ROYAL SOCIETY OF ARTS

The late Professor E. A. Minchin, M.A., F.R.S.

[See page 669

ROYAL SOCIETY OF MICRO

THE JOURNAL

OF THE

Quekett

MICROSCOPICAL CLUB

EDITED BY

A. W. SHEPPARD, F.Z.S., F.R.M.S.

SECOND SERIES.

VOLUME XII.

1913-1915.

London:

[PUBLISHED FOR THE CLUB]

WILLIAMS AND NORGATE,

14, HENRIETTA STREET, COVENT GARDEN, LONDON,
AND 7, BROAD STREET, OXFORD.

PRINTED BY
HAZELL, WATSON AND VINEY, LD.,
LONDON AND AYLESBURY.

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THE JOURNAL
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Quekett Microscopical Club.

THE FORAMINIFERA IN THEIR RÔLE AS WORLD-BUILDERS: A REVIEW OF THE FORAMINIFEROUS LIMESTONES AND OTHER ROCKS OF THE EASTERN AND WESTERN HEMISPHERES.

By Edward Heron-Allen, F.L.S., F.R.M.S., and Arthur Earland, F.R.M.S.

(*Read October* 22nd, 1912.)

Plates 1–3.

"*Life, as we call it, is nothing but the edge of the boundless Ocean of Existence where it comes on Soundings.*"—O. W. Holmes, *The Professor*, V.

Our late President, Prof. E. A. Minchin, F.R.S., in his last Presidential Address * dealt with certain organisms which he regarded as the simplest existing living structures, and speculated on the Origin of Life in this planet. Subsequently at the British Association Meeting at Dundee he led a most interesting discussion on the same subject, a discussion which left those who had the privilege of listening to it convinced of one fact at least, viz. that no two of the eminent men who took part in the debate were agreed on any single point. But as the earliest forms of life were necessarily of such a simple nature that they could by no possibility have been preserved as fossils, the interest of geologists may almost be said to commence with the stage in which life had become endowed with a sufficiently complex structure to leave recognisable remains in the geological record.

The Foraminifera would seem to constitute such a group. Of extremely simple structure, mere protoplasm without differentiation other than the nucleus, they yet possess the power either of secreting a solid shell from the mineral salts absorbed from

* *Journ. Q.M.C.*, Ser. 2, Vol. XI. p. 339.

their surrounding medium, or of building up adventitious shells by the co-ordination of foreign material obtained from their immediate environment. These shells, from their minute size and composition, are peculiarly adapted for preservation as fossils.

Hence, whatever the origin of life may have been, we might reasonably expect that among its earliest records would occur Foraminifera of simple and ancestral types, and that subsequent geological periods would show a constant progression in their development. Such, however, is not the case. So far as our geological knowledge carries us at present, the Foraminifera make their first appearance in the rocks in a highly differentiated stage, and among the earliest recognisable groups are many species which are still existing and dominant types to-day.

It is not so very many years, less than half a century in fact, since the sensational discovery of *Eozoon Canadense* (1) (2) (3) in the Laurentian rocks of Canada was hailed as evidence that the oldest fossil was, as might have been expected, a rhizopod. Into the long warfare which was waged round this fossil, in which the late Prof. K. Möbius took an active part (22), it is not proposed to enter in detail. But there was at the time of its discovery no greater authority on the Rhizopoda than the late Dr. W. B. Carpenter, a former President of this Club. He threw the whole weight of his authority into the scale in favour of the foraminiferal nature of *Eozoon*, and to the last was convinced of the soundness of his belief. But the balance of evidence has turned against him, and since his death but little interest has been shown in the question, *Eozoon* having been relegated by more or less general consent to the mineral kingdom.

We are, however, again threatened with a renewal of the controversy, for Mr. R. Kirkpatrick, of the British Museum, has recently announced in *Nature* that he is in possession of fresh evidence of the foraminiferal nature of *Eozoon*, and will shortly publish it. The microscopical world will no doubt await this evidence with interest, not unmixed, perhaps, with some trepidation at the reopening of this *chose jugée*. From the point of view of the subject of our paper, viz. "The Foraminifera as World-builders," definite proof of the rhizopodal nature of *Eozoon* would be very welcome. *Eozoon*, whatever its nature may be, occurs in enormous reefs in the Laurentian rocks of

Canada and elsewhere, and we should thus have evidence that even at this early stage of the world's history, the Foraminifera had commenced to play that important part in the formation of strata which they have continued in nearly all the successive periods of geological history, and which is still proceeding in the deep sea to-day. It is no exaggeration to say that, in spite of their diminutive size, the Foraminifera have played, and are still playing, a greater part in building up the crust of the earth than all other organisms combined.

Dismissing *Eozoon* for the present as *incertae sedis*, we find that the only other pre-Cambrian records which can be associated with Foraminifera are the peculiar bodies described by Cayeux (**4**) from certain quartzites and pthanites of the pre-Cambrian strata of Brittany. These are, however, of such minute size compared with other Foraminifera that their nature cannot be accepted on the evidence hitherto available.

It appears, therefore, that at present we have no unquestionable records of Foraminifera in pre-Cambrian rocks; but it is quite possible that such discoveries may be made in the future, as fossils of a higher type have been found, and it seems unlikely that Foraminifera did not, or could not, exist in seas capable of supporting such higher forms of life.

When, however, we come to the Cambrian strata we find the Foraminifera flourishing, and already marked by numerous widely separated types. So long ago as 1858 Ehrenberg (**5**) figured some internal glauconitic casts of Foraminifera from a clay near St. Petersburg, which is known to be of Lower Cambrian age. According to Chapman (**9**) these casts are referable to at least five genera, viz. *Verneuilina* and *Bolivina* (family Textularidae), *Nodosaria* (family Lagenidae), *Pulvinulina* and *Rotalia* (family Rotalidae).

Now it is noteworthy that none of these genera are of simple or primitive types, but are all comparatively complex in the arrangement of their chambers, and representing three distinct types of construction. Hence in this earliest geological record we find the group already well established, and markedly differentiated in structure. No monothalamous or primitive type appears in this earliest list, although we may be sure that they must have been in existence, both then and during antecedent ages.

Since the time of Ehrenberg there have been other discoveries of Cambrian Foraminifera in America (6) (7) and Siberia (8). We have not had an opportunity of seeing either of these reports, but it may be noted that the New Brunswick rocks furnished representatives of the pelagic genera *Orbulina* and *Globigerina* (family Globigerinidae), while the Siberian rock is described as assuming an oolitic structure on account of the numerous Foraminifera which it contains. It is therefore apparent that the Foraminifera had already assumed that dominant position which they have ever since maintained in the biology of the sea.

Turning to our own country, the oldest Foraminifera yet recorded are those described by Chapman (9) from a limestone of Upper Cambrian age near Malvern (Pl. 1, fig. 1). This record is of great interest because all the Foraminifera described are either monothalamous (genera *Lagena*, *Spirillina*) or polythalamous shells of simple type (genera *Nodosaria*, *Marginulina*, *Cristellaria*). As will be seen from the rock section figured by Chapman, the Foraminifera of one genus, *Spirillina*, form a considerable proportion of the entire mass of the rock (Pl. 1, fig. 1). The other species described are stated to have been of very rare occurrence. Now *Spirillina* is one of the simplest conceivable types of rhizopodal shell structure, an undivided tube coiled on itself in one plane, and is theoretically one of the forms which might be expected to turn up in the earliest records. Chapman has on certain minor points of structure instituted a new species (*Spirillina Groomii* Chapman) for this Cambrian type, but it appears to be nothing more than a variety of *Spirillina vivipara* Ehrenberg, a species which at the present day occurs on muddy bottoms of moderate depth in all parts of the world.* So far as we are aware, however, there is no other record of its occurrence in sufficient abundance to form a noticeable constituent of any deposit, recent or fossil. In recent dredgings it cannot be described as an abundant species.

In the next period, the Silurian, there are many records (10) (11) (12) (13) of Foraminifera, but they do not appear to be numerous. Brady (12) records and figures four species of the

* Since this was written specimens resembling *Spirillina Groomii* (Chapman) have been found in dredgings made in Blacksod Bay, Co. Mayo, and also in the Moray Firth. They will be described and figured in the forthcoming report on the Foraminifera of the Clare Island Survey.

simple type *Lagena*, which are still existing, and of world-wide distribution. These and the *Spirillina Groomii* of Chapman (= *S. vivipara* Ehrenberg) are therefore probably the oldest living types now in existence.

Of greater interest is the recording by Chapman (**14**) and Vine (**15**) of two genera of arenaceous Foraminifera, viz. *Hyperammina* and *Stacheia* from rocks of the Wenlock series. These constitute, so far as we are aware, the earliest evidence of the existence of arenaceous Foraminifera. The geological record does not furnish any evidence in support of the theory, so frequently postulated, that the earliest Foraminifera were types with adventitiously constructed tests; nor do we see any reason for accepting this theory. The property of secreting mineral salts from the surrounding medium is common to organisms of all grades, whereas the power of selecting and utilising foreign material seems to indicate a later and higher stage of development. There appears to be no geological reason why the composite tests of arenaceous Foraminifera should have escaped fossilisation, when the delicate shells of calcareous genera were preserved, had the two groups been in existence together in pre-Silurian times.

The Devonian period, according to Chapman (**16**), presents but a single record of Foraminifera, viz. those discovered by Terquem (**13**) at Paffrath in the Eiffel. Chapman comments on the singular absence of Foraminifera in the Devonian seas, where the conditions for their existence appear to have been favourable.

With the next period, however, the Carboniferous, the Foraminifera first begin to justify the title of our paper as World-builders. Various genera make their appearance in such numbers as to form enormous deposits. In the lower Carboniferous strata the large arenaceous species known as *Saccammina fusuliniformis* (McCoy) = *S. Carteri* (Brady) (**17**) is the principal constituent of enormous areas of limestone in Great Britain and on the Continent (Pl. 1, fig. 2). The upper Carboniferous limestone, on the other hand, is in most regions of the world largely built up of the shells of *Fusulina*, a perforate foraminifer belonging to the family Nummulinidae. Other genera which are largely concerned in the formation of Carboniferous limestones are *Endothyra* (Pl. 1, fig. 3) and *Archaediscus*, while in this period

occur the first records of two genera, *Amphistegina* and *Nummulites*, which in later times were destined to play an important part in the formation of the world's crust.

The Permian and Permo-Carboniferous rocks show a decline in the importance of the Foraminifera. Perhaps it would be more correct to say that there is a falling off in the records of those large and dominant types which marked the Carboniferous period. Foraminifera of many different genera occur in the Permo-Carboniferous rocks, but they are usually of comparatively small size, and so do not readily form a basis for rock formation. But in New South Wales and Tasmania, *Nubecularia*, which is the lowest type of imperforate foraminifer, forms a principal constituent of some limestones (**18**) (Pl. 1, fig. 4).

The Trias yields no strata in which Foraminifera are the principal constituent. Foraminifera occur in many horizons, but do not constitute any large proportion of the fauna. Perhaps the richest deposit is that described by Chapman (**19**) from Wedmore in Somerset.

Similarly in the Jurassic period, the Foraminifera, although often varied and abundant, are not responsible for any important proportion of the whole bulk of the formation. They are often confined to limited zones, in which they occur in great abundance, but the species are nearly all minute and completely masked as to external appearance by other material. The most important feature of this period, however, is the sudden bursting into active existence of numerous hyaline types, principally Lagenidae, hitherto more or less unknown. They occur in the clays of the Lias of the Continent in enormous variety, passing insensibly from one species into another, and the meticulous precision of Terquem and others who have monographed these strata has embarrassed the rhizopodist with a wealth of synonyms.

Up to this period the arenaceous Foraminifera have not presented any great diversity of forms, although, as we have seen, certain genera (*Saccammina*, *Endothyra*, etc.), have played an important part in building up strata. But Haeusler (**20**) (**21**) has described a most interesting series of arenaceous types from a sandy marl of Jurassic (Oxfordian) age in the Canton of Aargau (Switzerland), which includes many genera now known to us only from deep water. It is altogether one of the most pronounced and characteristic rhizopodal faunas recorded in the

fossil condition. The occurrence of this rich series of genera, some of which appear to be confined to this formation while others are hardly known except in the recent condition, suggests that the arenaceous foraminifera have, with few exceptions, always been confined to the deep sea, and that their scanty geological history may be due to that fact, and to the rarity of ancient deep-sea deposits.

Passing to the Cretaceous period, we find the Neocomian and Aptian strata comparatively devoid of recognisable foraminiferal remains. But it is almost certain that Foraminifera of the smaller types existed in enormous numbers in the seas of these periods, leaving their evidence behind them in the shape of the glauconitic casts and grains which bulk so largely in the Green-sands.

The Gault of England and the Continent contains a rich and varied foraminiferal fauna running into several hundred species. But although the Rhizopoda must have swarmed in the Gault seas, they do not constitute any large percentage of the total mass of the formation, and are often confined to limited zones.

The same remark may be applied to the numerous beds of chalk ranging from the Chalk Marl to the Upper Chalk. It is one of those popular beliefs which die so hard that chalk is made up entirely of the shells of the Foraminifera, and the textbooks and microscopical works abound with statements to that effect. Some of the methods suggested to students for the obtaining of specimens can only have originated in the fertile brains of the authors. The beginner is instructed to obtain a lump of chalk and scrub it to fragments with a toothbrush under water; or to place some lumps in a bag and smash them up with a hammer, subsequently kneading the mass under a tap until the water runs away clear. It is needless to say that such methods can never produce anything but debris and disappointment. These methods, together with directions for the adequate preparation of chalk material for examination, have been fully discussed by Heron-Allen in his "Prolegomena" (**23**).

There are very few zones in the Chalk which do not contain Foraminifera, but their number is as a rule small compared with the whole bulk of amorphous matter. But it is probable that in the Chalk sea the Foraminifera really abounded, and that the amorphous carbonate of lime is derived largely from

their comminuted and dissolved remains subsequently reprecipitated.

Certain zones of the Chalk, notably the zones of *Holaster planus* and *Micraster*, yield Foraminifera in larger numbers, but even here a section of the rock will show their limited distribution. The bulk of the organic remains will be found to consist of small spherical bodies which when cut in section show as rings (Pl. 2, fig. 1). These, the so-called "Spheres" of the chalk, are perhaps the origin of the belief that chalk is built up of the shells of Foraminifera. But whatever the "Spheres" may be, we are convinced that they are not Foraminifera. Their nature is still in doubt, although they have been relegated in turn to the Foraminifera, the Radiolaria and the Diatomaceae. Mr. W. Hill, F.G.S., of Hitchin, whose knowledge of the microscopic structure of chalk is unrivalled, and who has devoted many years to the study of these "Spheres," has published a scheme for the division of the Chalk into zones, based on their occurrence and numbers (**32**), but he is still unable to explain their origin and nature. We suggest that they may be the chitinous tests of flagellate infusoria such as are found in great numbers in the sea to-day, of practically identical size and shape.

The Chalk of Maestricht is rich in Foraminifera, and may be regarded as the starting-point of the rich Foraminiferal fauna of the Tertiary period, as it contains many large genera, *Orbitolites*, *Operculina*, *Orbitoides*, etc., which reached a maximum of development and distribution in Eocene and Miocene times.

Passing into Tertiary times we reach the Golden Age of the Foraminifera; the age in which they were to reach their maximum development both as regards size and abundance, and to leave their remains in great beds extending across whole continents, and often of an enormous thickness.

These Tertiary Foraminifera are very sparingly represented in Great Britain. The London clay, although it contains a rich rhizopodal fauna in a limited zone, is on the whole absolutely barren, and the Thanet Sands and Woolwich and Reading beds have yielded few records.

In the Bracklesham beds of Hampshire, however, we find a zone almost entirely composed of two or three species of *Nummulites*. At Selsey Bill the foreshore at low tide, on the east shore,

is for a large area covered with an exposure of this zone (the "Park" beds), and one cannot walk without crushing vast agglomerated masses of *Nummulites laevigatus*, extending for miles and occupying broad areas between tide-marks.

Off the extremity of Selsey Bill lies the extensive reef known as "The Mixon." It is exposed at low tide, and is then found to be a limestone principally composed of one species of foraminifer, *Alveolina Boscii* Defrance. Other species (notably a large alveoliniform *Miliolina*, *Nummulites*, and a large *Polymorphina*) are to be found in the rock, but this is dominant (Pl. 2, fig. 2). *Alveolina Boscii*, which has built up enormous areas of limestone extending across Southern Europe to the Himalayas, is still in existence to-day, and is now forming similar deposits off many tropical shores. The Selsey specimens—the only ones to be found in Great Britain—are indistinguishable from those to be dredged in shallow water to-day, off the Great Barrier Reef of Queensland and in many other places (**24**).

At Stubbington and its neighbourhood, in Hampshire, smaller types of Nummulites, viz. *Nummulites elegans* and *N. variolaria*, are to be found in similar abundance.

Turning to the Continent, we find these Nummulitic and Alveoline limestones developed to an incredible extent. With interruptions here and there, they spread in a broad band across Europe, Asia and Northern Africa to the Himalayas, attaining in many places a thickness of several thousand feet (Pl. 2, fig. 3). The species vary with the zone and locality, but, as a rule, the whole rock is built up of their more or less perfect remains, and under the microscope the very debris in the interstices of perfect specimens is found to consist of their comminuted remains (Pl. 2, fig. 4 and Pl. 3, fig. 1).

Among the more familiar instances of Nummulitic limestone may be mentioned the Pyramids of Egypt, which are built of limestone quarried in the neighbouring Mokattam Hills, largely composed of a single species of Nummulite—*N. Gizehensis* (Ehrenberg). We illustrate in Plate 3, fig. 1 a section through a microspheric specimen of this Nummulite, one of a series collected for us by Mrs. A. M. King, F.R.M.S. The peculiarity of these remains struck the geographer Strabo, who accounts for their presence in the limestone by asserting that they were the petrified remains of lentils from the rations of the ancients who built the

Pyramids.* They are to this day known locally as "Pharaoh's beans." †

Philip de la Harpe begins his Monograph on the genus (**27**) with the words, "Egypt is the classic land of the Nummulites," and Dr. Carpenter in his Introduction (**28**) passes in review the legends which have attached themselves to this organism, from Herodotus (?), Pliny (?) and Strabo to the learned Clusius, who refers to "the popular belief of the Transylvanians that they were pieces of money turned into stone by King Ladislaus, in order to prevent his soldiers from stopping to collect them just when they were putting the Tartars to flight!" ‡

It may be remarked that Prof. Haug has suggested (**31**) abolishing the Lyellian nomenclature of geological periods for all epochs later than the Cretaceous, and the redistribution of the strata into Nummulitic, Neogene, and Quaternary. He suggests that the Nummulitic, whose classification is founded solely upon this foraminifer alone, shall be divided into the Eo-Nummulitic, which will comprise the Montian, the Thanetian, and the Londonian (names which speak for themselves), the Meso-Nummulitic, which will comprise the Lutetian and Ludian, and the Neo-Nummulitic, which includes all strata from the Lower Oligocene up to the dawn of the Glacial Period—which commences his Quaternary.

As a rule these two dominant types, *Alveolina* and *Nummulites*,

* Strabo, *Geographica*, lib. xvii. cap. i. § 34: *φασὶ δ'ἀπολιθωθῆναι λείψανα τῆς τῶν ἐργαζομένων τροφῆς. οὐκ ἀπέοικε.* See the note on this passage in Canon Rawlinson's translation (1860).

† In spite of the fact that Herodotus (who has been credited with Strabo's observation on the Nummulites) expressly states (*Euterpe*, II. § 37) that the Egyptians never grew or ate beans in any form.

‡ Clusius (*i.e.* Charles de l'Ecluse, 1526–1609), in *Caroli Clusii et aliorum epistolae*, Paris (Epistola xxxvii.), thus records the matter: "Intellexi item genus quoddam lapillorum planorum et quasi circino in orbem ductorum inveniri in montibus qui Pannoniam a Dacia sive Transilvania disterminant, quorum alii auri, alii argenti colorem referunt et characteribus insigniti videntur sed incognitis. Ferunt Ladislaum regem quum Tartaros praeda et spoliis onustos persequeretur atque metueret, ne militum suorum avaritia et ignavia, qui thesauris per viam stratis ab hostibus inhaerebant, victoria illi e manibus eriperetur, a Deo petiisse ut nummi illi et pecunia ab hostibus in via relicta in lapides mutarentur, quo militem sic delusum alacriorem haberet in persequendo hoste." A passage contemporary with, if it should not precede, Mr. C. D. Sherborn's earliest reference to Conrad Gesner (1565).

do not exist together, but the transition from one dominant to the other is often quite sharp. We show a section from Sherani, on the N.W. frontier of India, illustrating the junction of the two beds. Within a thickness of two inches the rock turns from a Nummulitic to an Alveoline limestone (Pl. 3, fig. 2). What possible explanation can there be for such a radical and cataclysmic change, necessitating the practical extinction of one dominant, and the sudden rise to prominence of another, widely different, type? It cannot be a case of evolution, as the two species represent entirely different types of structure.

With the passing of the Eocene period the Foraminifera lose their all-important position as rock-builders. Through Oligocene and Miocene times they continued to flourish, and to form deposits largely or entirely built up of their remains. The genus *Nummulites* dies out, dies so completely that at the present day it is represented by only a single small species of rare occurrence in tropical seas. *Alveolina* persists, but no longer as a dominant. *Orbitoides*, a highly specialised type which had made its first appearance in the Chalk of Maestricht, attains sudden abundance and forms great beds of Orbitoidal limestone in all the Continents, only to die out absolutely in the Miocene (Pl. 3, fig. 3). But the Miocene and later Tertiary deposits, though often presenting an abundant and extremely varied foraminiferal fauna, no longer owe their existence to the occurrence of one or few species in enormous numbers, except in those comparatively few deep-sea deposits which have been raised to the surface in the West Indies, New Guinea and the Pacific, and which are similar in structure and often in species to the deposits which are being found in the deep sea to-day (**25**) (**26**) (Pl. 3, fig. 4).

Perhaps the conditions under which foraminiferal life exists to-day may help to explain the change. We have now no seas swarming with Nummulites and Alveolina, to the practical exclusion of other species Here and there about the world the shallow-water Foraminifera are to be found in such profusion that, given favourable means of preservation, we should have in time a true foraminiferal limestone. From the shallow waters of the West Indian seas we have received dredgings almost entirely composed of the genera *Orbiculina* and *Miliolina*. In the shallow lagoons of the Pacific *Tinoporus baculatus*, *Alveolina Boscii* and

Orbitolites complanata still form banks which impede navigation. But speaking generally, the activity of the Foraminifera to-day is displayed in another sphere. In the surface waters of the great oceans the few genera which are found in the pelagic condition swarm in countless numbers, and their dead shells falling constantly to the sea floor, are there building up layers of Globigerina ooze which, if solidified and raised to the surface, would be visible as areas of foraminiferal limestone exceeding even the Nummulitic limestones in extent.

Murray and Renard estimate the area of sea bottom over which Globigerina ooze is at present in process of formation at over 49½ million square miles. Of its depth we can, of course, form no idea, but as the great oceans are practically permanent, it must be very great, because we know from deep-sea deposits which have been elevated into land surfaces in Malta, Barbados, Trinidad and Australasia, that similar deposits have been forming in the deep sea ever since at least Miocene times.

Prof. Agassiz has observed (**29**): "No lithological distinction of any value has been established between the chalk proper and the calcareous mud of the Atlantic," and it has been reasonably postulated by Prof. Jukes-Brown (**30**), after a careful analysis of calcareous oozes, that the chalk was deposited in a sea of less than 500 fathoms, though doubtless at a considerable distance from land. The time occupied in the deposit of the English chalk, arguing by the rate at which the Atlantic ooze is formed, which is one foot in a century, must have been 150,000 years.

We cannot but feel that this paper has already overpassed the reasonable limits of such a communication, but our difficulty has been mainly one of selection. The matter is one whose ramifications are almost infinite. A systematic study of the dynamics of the subject remains yet to be completed, though significant beginnings have been made by Prof. Hull and by Prof. Jukes-Brown. A careful consideration of the factors which have led to the deposition of certain forms of Foraminifera and other microzoa in an orderly sequence, dependent for the most part upon current action and specific gravity, must lead us to an understanding of the forces which have accounted for the Building of the World in the form in which we know it. And it is by the study of such factors, as revealed by their results,

that geologists have been able to reconstruct the geographical features of ages inconceivably remote.

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Description of Plates 1—3.

With the exception of Pl. 1, fig. 1, Pl. 3, fig. 4, the figures are from original sources.

Plate 1.

Fig. 1. Spirillina Limestone. Upper Cambrian, Malvern (after Chapman, *Q.J.G.S.*, vol. lvi., 1900, Plate 15).
,, 2. Saccammina Limestone. Carboniferous. Pathhead, Haddington, N.B.
,, 3. Endothyra Limestone. Carboniferous. Indiana.
,, 4. Nubecularia Limestone. Permo-carboniferous. Polkolbin, Maitland, N. S. Wales.

Plate 2.

Fig. 1. Middle Chalk. Zone of *Rhynchonella Cuvieri*. Hitchin.
,, 2. Alveolina Limestone. Eocene. Mixon Rock, Selsey.
,, 3. Alveolina Limestone. Eocene. Bunnu, N. W. Frontier India.
, 4. Nummulitic Limestone. Eocene. Gizeh, Egypt.

Plate 3.

Fig. 1. *Nummulites Gizehensis* (Ehrenberg), microspheric specimen. Horizontal section, through primordial chamber.

„ 2. Alveolina and Nummulitic Limestone. Eocene. Shiranni, N. W. Frontier, India, showing the junction of the two beds.

„ 3. Orbitoidal Limestone. Miocene. Japan.

„ 4. Globigerina Limestone. Miocene. Bismarck Archipelago, Pacific (after Schubert, *loc. cit.*, Plate 5, fig. 4).

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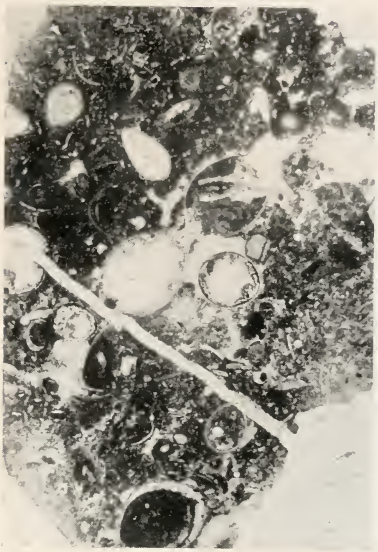

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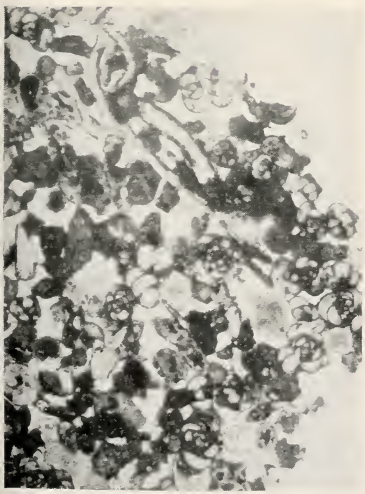

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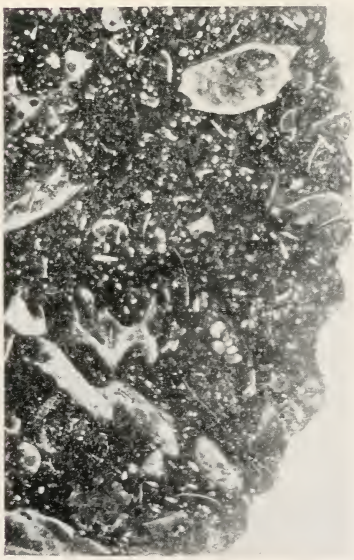

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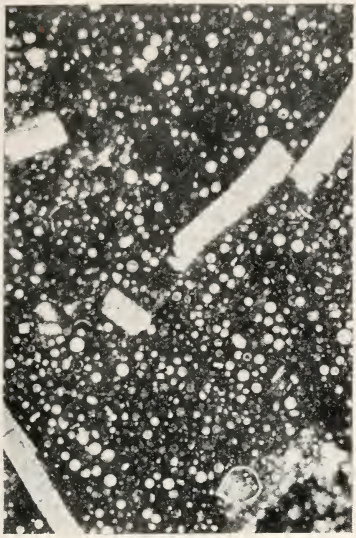

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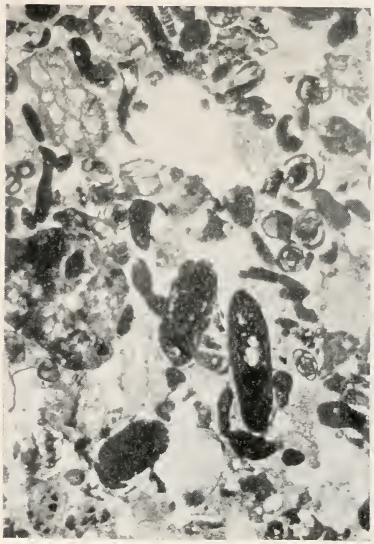

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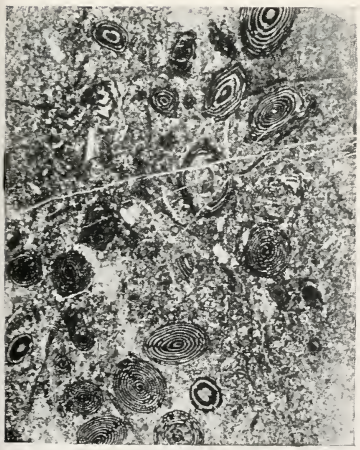

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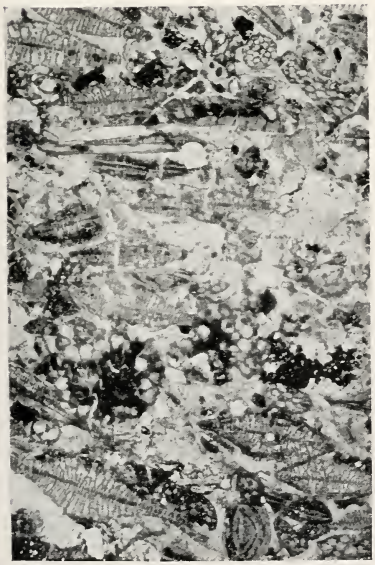

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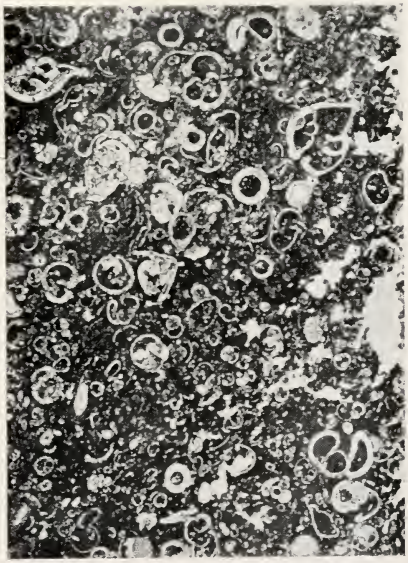

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Foraminiferal Limestones.

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NOTES ON SOME OF THE DISCOID DIATOMS.

By W. M. Bale, F.R.M.S.

(*Contributed by Prof. A. Dendy, January 28th*, 1913.)

In the following notes, written for the most part several years since, I have attempted, in somewhat desultory fashion, a survey of some of the principal characters which have been utilised in the discrimination of species in three or four of the best-known genera of discoid diatoms. Some of the conclusions at which I have arrived as to the inadequacy of many of these distinctions have, I am aware, been reached by previous observers, more especially in the genus *Coscinodiscus*; but in such cases the special instances now brought forward may perhaps be serviceable in reinforcing those conclusions. In other cases, particularly in the genus *Actinoptychus*, my observations tend to prove that characters accepted as specific even by recent authors are demonstrably unreliable. I have not pursued my investigations more fully, as I have found the subject too difficult, owing to the impossibility of procuring much of the literature, and to my total isolation from other observers. I trust, however, that these notes may not be without interest for students of the Diatomaceae, and that the suggestions therein may be of some value to those who occupy themselves with their classification.

Coscinodiscus.—Notwithstanding all that has been done towards the elucidation of this unwieldy genus, it still remains the most difficult—as it is the most extensive—of the whole order. This follows naturally from the general similarity of form, and the absence in most cases of any specialised areas or conspicuous appendages such as serve to distinguish the species in *Actinoptychus*, *Auliscus*, etc. Many forms which have been described as

distinct differ only in having the markings a little smaller or larger, while others are characterised by trifling distinctions of detail which, on examination of an extended series of specimens, are found to break down utterly. On the other hand it will be seen that, in many instances, details which might be helpful in the discrimination of species have been generally overlooked.

The first serious attempt to grapple with the difficulties involved in the classification of the genus was that of Grunow, in his work on the Diatoms of Franz-Josef Land, a perusal of which leads one to regret that this acute observer did not carry out a more comprehensive survey of the whole genus. Rattray's *Revision*, though giving evidence of a vast amount of painstaking research, is far from final in regard to the species admitted, many of which are characterised by features obviously not of specific—sometimes not even of varietal—value. Moreover, in working over slides from well-known deposits, one finds many forms which it is impossible to place under any of the species described, though it is most unlikely that Rattray could have failed to observe them. The impression is produced that many of the descriptions have been framed on particular specimens, without any allowance for the range of variation usually present. The "key" is minimised in value owing to the use in many of the sections of characters which are quite inconstant, or which may characterise the type but not the varieties, while the attempt to include all the sections in one key has added much to the difficulty of the undertaking, and has involved mistakes which render it in some cases quite unreliable. (As an example, let the observer take a typical valve of *C. asteromphalus* and attempt to trace it through the key, and he will fail to find it. But it appears under Section 116, and, if followed backwards, it will be referred to Section 111, where the description is, "Markings rounded, granular; interspaces hyaline, unequal, rows radial," which obviously cannot apply to the species at all.)

Nevertheless Rattray's work undoubtedly represents a great advance in its suppression of a large number of pseudo-species, though one cannot but regret that the process has not been carried further.

Mr. Cox, going to the opposite extreme, would reduce all the multitudinous forms of *Coscinodiscus* to seven species, *Actinocyclus Ehrenbergii* being included as one of them. Some diatomists

have expressed approval of this proposal, but none have adopted it, nor are any likely to do so.

In surveying the various characters by which species may be defined, the outline will naturally be the first to be considered. This in the Coscinodisci, however, is of little assistance, as, except in a few aberrant species, the circular form prevails. Passing to the surface contour, we have a character which has been utilised by Grunow, Rattray, and others, but by no means so fully as might be. Thus neither of these observers, in differentiating *C. asteromphalus* from *C. centralis*, refers to the fact that the former has usually the centre depressed, while the latter is convex throughout. In several cases the absence of information on this point in Rattray's descriptions just renders the diagnosis doubtful. And this is the more important from the fact that even a good figure does not always bring out this special point. At the same time it may be observed that it is not rare for individuals of a given species to depart from the normal character in regard to surface contour, and further, that in particular localities this variation may prevail. This refers especially to a tendency for the surface to be more depressed than is normally the case, and does not apply to *Coscinodiscus* only. Thus in some of the Oamaru deposits we find that *Aulacodiscus margaritaceus*, *A. amoenus* and the large forms of the *Triceratium favus* group are all characterised by the unusually depressed surface of the valves.

It may be noted, further, that it is not safe to describe the surface contour of a species without examining both valves. Rattray describes *C. superbus* as convex, but in reality one valve is convex, while the other has the centre depressed. Several species, such as *C. tumidus*, have the surface concentrically undulated, while in a series of forms, described by Grunow as *Pseudo-Stephanodiscus*, there is an asymmetrical inflation of the surface. The inflations and depressions in *C. excavatus* are also familiar examples of specialised areas.

Variations of the radial symmetry, other than those mentioned, are rare. A notable instance is that of *C. cocconeiformis*, which has the markings bilaterally arranged.

In the great majority of cases the form, size and arrangement of the cellules or puncta which cover the surface are the principal or sole ground relied upon for specific distinction, many

so-called species being differentiated solely by slight variations in the size of the areolation, or by its increasing or decreasing in size towards the margin. All such species, unless other and weightier differences can be found, should be swept aside as spurious. The same remark applies to the presence or absence of a central area, of a central rosette of larger areolae, of bright points at the origin of the shorter radial series, of parts of the surface where the polygonal areolation is replaced by separate circular cellules, and of fine punctate secondary markings. Any of these characters *may*, of course, be constantly associated with a particular species; but, in many species at any rate, examination of a sufficient series readily shows that they may be indifferently present or not. Indeed, within the limits of the single species *C. asteromphalus* a range of forms may be found some or other of which exhibit every one of the characters just mentioned, while others show none of them.

In some respects the size of the valve (*i.e.* with reference to the average of the species) is a determining factor in the arrangement of the markings. Thus in such forms of *C. radiatus* as are usually considered typical there are commonly three or four slightly larger cellules in the centre, and the rest are in distinctly radial series. In smaller valves the central cellules are no longer than the rest, and in the smallest forms the radial disposition of the cellules is totally lost. A still more striking instance is found in one of the robust forms of *C. asteromphalus*, common in some of the North American deposits. The largest valves have a conspicuous central rosette of large cellules, and outside these the areolae are much smaller, gradually increasing in size, however, to the mid-radius. With a diminution in the size of the valve comes a modification in the direction of levelling down the differences in size of the areolation—the rosette-cells become smaller, and those next to them larger in proportion. One stage in this series is the *C. biangulatus* of Schmidt, which is only a normal form of this group, and by no means of specific or even varietal value. In the smallest forms of the series all trace of the rosette is wanting, the areolae are fairly uniform in size throughout, and the centre of the valve is not depressed as in larger specimens, but convex or very slightly flattened, while in many valves the cellules are separate and circular on part of the surface, as in *C. perforatus* and *C. apiculatus*. Similarly the

C. crassus, so abundant in the Sendai deposit, simply consists of the smaller valves of the equally abundant *C. borealis*, to which it bears the same relationship that *C. biangulatus* does to *C. asteromphalus*.

In *C. marginatus* the small valves, with uniform and non-radial areolation, are considered typical, but, as in the above-mentioned species, we find that valves of maximum size have the areolation distinctly radial, with the areolae increasing in size from the central rosette towards the margin.

In other species similar conditions occur, indicating that the reduction of the differences in size of the areolae is the regular concomitant of the reduction in size of the valves, and showing how little such variations are to be relied on as specific distinctions.

The presence of a central area may be of specific value in some instances, but in many species it is quite worthless even as a varietal character. Sometimes its disappearance is due to the cellules surrounding it becoming enlarged at its expense. Thus in *C. perforatus* and *C. apiculatus* normal valves (if indeed we are right in considering as normal those valves with separate round markings, which I greatly doubt) have a blank central space, and the cellules surrounding it are in no way different from the rest, but when, by the enlarging of the cellules generally at the expense of the intervening substance, the structure becomes areolate, the most central cellules often enlarge inwards till they obliterate the area, and thus form a rosette, as in *C. Oculus Iridis*, etc.

Far too much importance has been attached to the area in Rattray's monograph, especially in the key.

The central rosette is one of the most variable of characters. In some cases, as already mentioned, it is conspicuous in the largest valves, dwindling and finally vanishing in the smaller ones; in others, just alluded to, it results from the obliteration, entire or partial, of the central area. In some no doubt it may be regarded as a fairly constant specific character.

The tendency in some species for the polygonal areolation to be replaced on a portion of the valve by isolated circular cellules may be briefly referred to. *C. perforatus* and *C. apiculatus* are familiar cases in which this modification occurs, either over the whole surface of the valve, or on more or less of one side, while

in *C. gigas*, *C. diorama*, and a few others, it is the central part of the valve which is so modified. Though in *C. apiculatus* and *C. perforatus* it is universally recognised that this peculiarity is not of specific importance, the loose disposition of the markings in the central part of such species as *C. diorama* has been made use of to characterise the species, but in some cases at least unwarrantably. In a species found in Port Phillip the larger valves have the markings as in *C. diorama*, while the smaller ones are areolate throughout. When the modification in question occurs in the central part of a valve it is usually associated with a thinner condition of the silex, but this does not appear to be the case in such species as *C. perforatus* and *C. apiculatus*.

In rare cases the loosely disposed and rounded markings occur on an annular area, concentric with the margin, and an interesting example of this is found in the large, robust form of *C. Oculus Iridis* found in the Mors deposit. It is a variable form as regards the surface contour, but commonly in large valves the centre and the sub-marginal zone are about equally elevated, and the intervening broad annular area is slightly depressed. A varietal form differs in having this depression much deeper, and, on the outer side, very abrupt, while in a third form the annular depression is very deep and narrow, and on the bottom of the depression the cellules are rounded and separate (a condition to which there is sometimes a tendency in the second form). This last variety was described by Grunow in his work on the diatoms of Franz-Josef Land as a new species, under the name of *C. annulatus*, notwithstanding which it was figured later on Pl. 184 of Schmidt's Atlas under the name of *Craspedodiscus Mölleri*.

I have also seen a form of *C. excavatus*, very near to Grunow's var. *semilunaris*, in which there is a complete annular depression, with round markings, not far from the centre.

The circular areas of the varieties just mentioned, as well as the inflations of ordinary forms of *C. excavatus*, are all instances of abrupt bulging in (or out) of the substance of the valve, and in all of them the portion which is subject to this bulging appears thinner than the rest of the valve, while the markings are fainter, as well as being rounded and loosely disposed.

The occurrence of " bright points " at the origin of the shorter radial series of cellules has been commonly regarded as a valid

specific character. In some instances these "bright points" are merely the optical expression of a local thickening of the silex; more generally, however, they are true cellules, differing from the rest in their minute size. They are conspicuous in *C. perforatus*, and they form the principal ground of distinction between that species and *C. apiculatus*. But in examining a large series of *C. perforatus* var. *cellulosa* I find them by no means so constant as to justify the importance attached to them. While in some valves they appear at the origin of all, or nearly all, the shorter rows of areolae, in others they are much sparser, and in a few cases I failed to detect more than four or five on the whole valve. In such cases, and when, as often happens, the central area is obsolete, it is a critical matter indeed to distinguish the valve from *C. radiatus*, and in passing I may note that the "*C. radiatus*" of my Möller's Typen-Platte is just one of these valves of *C. perforatus* var. *cellulosa*, with all its bright points complete. *C. obscurus* may be mentioned as another species in which the bright points, usually present, may be either totally absent or reduced to a very small number. On the other hand the points often occur in species which are normally without them. I have met with instances of this kind in *C. asteromphalus*, on a narrow unilateral area where the cellules are separate and rounded. In a slide from Cambridge, Barbados, there are numerous valves of *C. excavatus*, most of which display these minute cellules, and in some valves not only at the origin of the radial series, but profusely interspersed among the large areolae all over the surface, even in places other than the angles of the areolae. And I have a curious valve of *Endyctia oceanica*, in which these minute cellules form the principal part of the areolation, the ordinary large cells only existing in scattered groups of four or five, surrounded on all sides by the network of small ones.

I have referred already to the small importance to be attached to mere differences in the size of the areolation, but I would further remark that it must by no means be assumed that only *small* differences are to be disregarded. Valves of *C. concinnus* may have only four cellules in 0·01 mm., while others may have as many as twelve, though the valve may be much larger. And I have seen a frustule of *C. excentricus* in which one valve was twice as finely marked as the other. Such instances show forcibly the futility of distinctions founded on the size of the areolation.

The structure of the valve-border is a feature which has not always received sufficient attention from observers, who have overlooked peculiarities which might be of service in classification. This refers to the general character of the border, and more particularly to the minute appendages which it frequently bears. The apiculi which form a circlet at the margin of many species are familiar to all observers, more especially those which in some of the Fasciculati and Cestodiscoidales attain a prominence which could not fail to attract attention. But those which are asymmetrical, and of which only one or two appear on each valve, have hitherto singularly escaped notice, except in a very few instances, where they are more conspicuous than usual. For example, in the robust form of *C. lineatus*, described as *C. leptopus*, a single larger apiculus, farther in than the rest, is quoted by Rattray as distinguishing *C. leptopus* from its allies. Yet in fact it is not peculiar to this form, a similar apiculus, but more delicate, being easily discoverable in other and more nearly typical forms of *C. lineatus*. Further, it is equally a feature of *C. excentricus*, and I find it commonly present, though apparently hitherto unnoticed, in forms of that species from such different localities as Port Phillip, Cuxhaven, Santa Monica, and Peru and Bolivia guanos. (There is, of course, no justification for the line of demarcation drawn by Rattray between the respective groups of the Lineati and the Excentrici. The two type species are connected by intermediate forms, and the same remark applies to *C. excentricus* and *C. subtilis*.)

Among the Radiati the tendency is towards the production of *two* apiculi, which occupy positions about one-third or one-fourth of the circumference apart. They are found in many species, though strangely enough I can find no mention of them by any observer except in the cases of *C. concinnus* and *C. centralis*, in both of which forms they are very conspicuous. Rattray says that *C. centralis* is distinguished from *C. asteromphalus* by these apiculi, and cannot be united with it in the same species, as proposed by Grunow. An unfortunate dictum, since all, or nearly all, of the numerous varieties of *C. asteromphalus* agree precisely with *C. centralis* in this respect, while such apiculi, but more rudimentary and indefinite, are found in a wide range of forms comprised under *C. marginatus*, *C. perforatus*, *C. apiculatus*, *C. borealis* and others. Their minute size and indefinite form

cause them to be easily overlooked against the coarsely marked background of the valve-areolation, but in *C. concinnus* and *C. centralis* they are more conspicuous, owing largely to the more delicate and transparent condition of the valve.

The key to the position of these apiculi is, however, to be found in certain modifications of the valve-border which occur in the vicinity, and which indeed are often obvious when it is difficult or impossible to detect the apiculi themselves. These modifications may take the form of a thinning away of the valve-surface (*C. marginatus*), or an apparent notching of the margin (*C. borealis*, *C. diorama*, etc.), or a sinuation of the *inner* edge of the thickened border (*C. asteromphalus*). In the last species this marginal structure is very conspicuous, at least in the robust valves, and it is shown in Schmidt's figures of *C. biangulatus* and one or two others.

In *C. perforatus* and *C. apiculatus* (at least in the areolate forms) two minute notches in the extreme margin of the areolation can in most cases be seen, and by careful examination the apiculi may generally be found opposite them, but they appear no more than a slight thickening of the silex, which would certainly never be noticed except for the marginal clue. In *C. marginatus* the coarse radial structure of the marginal zone is thinned away over two comparatively large areas, sometimes very noticeably, but the apiculi themselves are difficult to make out.

The apiculi are most fully developed in *C. centralis* and *C. asteromphalus*. They are best seen by examining the inside of a large valve in which the marginal part is steeply convex, so that the apiculi, which project into the valve a little above the rim, can be observed without the interference of an immediate background. The apiculus takes the form of a minute disc, attached by a central point, and bearing a sub-globular or irregular mass. The border in *C. asteromphalus* is usually widened inwardly so as to form an annular projection into the cavity of the frustule. The extent to which this widening takes place varies greatly, even in the same variety; but whatever its width, so long as it projects inwards at all, it is sinuated under the apiculi, which are always uncovered, so that the sinuations are deeper as the valve-border is wider. The structure would seem to imply the presence in the living organism of some direct communicating filaments between the apiculi of the two valves,

on which the inward extension of the border must never encroach. I have had no opportunity of proving whether this is so, or even of ascertaining whether the apiculi of the two valves are opposite, except in a single instance—a large cylindrical frustule of *C. mirificus* mounted in zonal view, and in this the apiculi *are* opposite.

In *C. gigas* the apiculi are, if present, obscure, and I can find no marginal indications of them. *C. diorama* and allied forms, however, often classed as varieties of *C. gigas*, have the border distinctly marked with two apparent notches as in *C. perforatus*. *C. concinnus* has distinct apiculi, and many specimens have in addition crescentic processes *outside* the valve, partly surrounding the point at which the apiculi originate. These valves are known as *Eupodiscus Jonesianus* Greville (*E. commutatus* Grunow), but I do not think they have any claim to rank even as a variety. They are abundant in slides from Cuxhaven, mixed indiscriminately with valves having the internal apiculi only.

While several forms besides those which I can identify with the foregoing species share in the peculiarity in question, there are many others in which I have failed to detect it. Such are the thick variety of *C. Oculus Iridis* found in the Mors deposit, also *C. radiatus*. In more typical forms of *C. Oculus Iridis*, however, careful search has disclosed two apiculi, which are simple bacillar projections into the cavity of the frustule.

Apart from these appendages the structure of the border itself has in many cases not received sufficient attention as a help in classification. Some species have distinct borders with markings quite different from those of the valve generally, others have the areolar structure continued to the extreme margin without interruption; in some the edge is turned over, in others it is quite flat, and frequently the specific diagnosis contains no hint of the character of the valve in this respect; so that of two valves, differing widely in this particular, it may be impossible to decide which of them corresponds with the specific description. *C. concinnus* and *C. centralis* may serve to illustrate this. Both are very convex, but in the former the marginal part is slightly flattened, the areolae diminish to a very minute size, and are succeeded by an extremely narrow hyaline border, thinning away so as to show only a smooth single contour. In a typical *C. centralis*, on the other hand, the valve curves downward to the

extreme edge, and the areolae are of an appreciable size throughout, while the border is not thinned away, so that on focusing the margin there is visible a distinct double contour, with the walls of the last row of cellules showing as coarse transverse striae.

Several species exhibit a tendency for the border to become wider in proportion as the valves are smaller. *C. obscurus* and *C. apiculatus* are instances of this. In both these species I have traced a series down to forms with wide borders, which are only to be distinguished with difficulty from *C. marginatus*. In Nottingham and other American deposits such forms of *C. apiculatus* are common, and one of them figured by Schmidt (Pl. 62, f. 11, 12) has been referred by Rattray to *C. marginatus*.

In several species of the Radiati the angles of the areolae often tend to become thickened, so that in a certain focus there appears to be a bead at each angle. This feature has no specific importance, and I agree with Rattray that the presence at each angle of a distinct spine, as occasionally found, is of no greater consequence.

I have already referred to the close affinity which exists between the Excentrici and the Fasciculati, *e.g.* between *C. excentricus* and *C. subtilis*. Grunow mentioned this affinity, but Rattray says that it is remote. Grunow's view is undoubtedly correct. In a typical *C. excentricus* there is a central cellule, and surrounding it a circle, generally of seven. Each of these seven is the centre of an arcuate line of cellules, extending to the margin on either side, behind which is a succession of similar arcuate series, so that the whole of the cellules may be regarded as forming seven fascicles, crossing each other symmetrically, so that no division-lines exist, and for the most part each cellule will form part of three different fascicles. In *C. subtilis* and *C. symbolophorus* the number of fascicles is greater, and the divisions between them more abrupt, especially in the central part of the valve, so that the fasciculation is more manifest, but even in these forms the fascicles blend towards the margin in the same way as those of *C. excentricus*. I have seen a frustule of the latter species in which one valve was normal, while the other was far more finely marked, and was as distinctly fasciculate as *C. subtilis*.

I should mention that the *C. subtilis* referred to is Grunow' typical form, which is quite different from Rattray's, though

that observer quotes Grunow as his authority. He describes *C. subtilis* as apiculate, and differentiates other species from it by the absence of apiculi. Yet Grunow says expressly that *C. subtilis* is non-apiculate. "Der Ausgangspunkt für alle diese Formen ist der *stachellose C. subtilis* (Ehr. partim), Gregory, Grunow" (*Diat.*, F.-Josef Land, p. 81). This form, which is similar to *C. symbolophorus*, but without the stellate markings at the centre, also agrees well with Rattray's own account of Ehrenberg's original species. It is not common, and Van Heurck figures it from guano, not finding it in European gatherings. But Peragallo, like Rattray, though claiming to follow Grunow's authority for the type, has figured and described a totally different form—an apiculate variety.

Actinocyclus.—The excessive multiplication of specific names which encumbers the Coscinodisci has not been carried out to a corresponding extent in the much smaller group of the Actinocycli (ignoring, of course, Ehrenberg's multitudinous pseudo-species); still there is no doubt that an undue regard for certain points of structure has led to the establishment of several species on insufficient grounds. Rattray's monograph admits about seventy species; some of these have no claim to recognition, but, on the other hand, I find that about fifteen out of thirty-four species or varieties which I possess cannot be identified with any of Rattray's descriptions. He has adopted in this monograph the plan of furnishing extremely long and minutely detailed descriptions, a method which renders identification more certain when one is dealing with the precise form described, but does not allow for the variations which constantly present themselves even in a single gathering. In fact, as I have remarked in reference to Coscinodiscus, many of these are not descriptions of species, but of individual diatoms. Mr. Rattray uses five places of decimals to express the fraction of a millimetre which corresponds to the diameter of a pseudo-nodule! Of what possible use can such measurements be when applied to structures so notoriously variable?

Before discussing the range of variation in the genus, and as I shall refer repeatedly to the commonest species—*A. Ehrenbergii*—I must premise that I use that name in the sense in which it is used by Ralfs himself, and by Van Heurck, Grunow, Peragallo, and, so far as I know, by all other observers except

Rattray, who has unaccountably assigned the name to an entirely different form, while describing the true *A. Ehrenbergii* as *A. moniliformis* Ralfs. *A. Ehrenbergii* was described by Ralfs from his own knowledge, while *A. moniliformis* was merely a name given by him to certain forms from Oran and Virginia, which he had not seen, but which he judged from Ehrenberg's figures to be distinct, the distinction consisting in the division of *A. Ehrenbergii* into compartments by double lines, while *A. moniliformis* was divided by single ones. There is really no difference, except such as depends on the size of the valves and the number of the fasciculi. In small valves, containing few fascicles, the interfasciculate rays form a wide angle with the other series, and are therefore very marked; and these are the "single series of dots" referred to by Ralfs. In large valves the fascicles are numerous and narrow, so the interfasciculate rays form a small angle with the other series, which, stopping short at various points, leave a double row of subulate blank spaces along the sides of each primary or interfasciculate ray, and these subulate areas constitute the "double lines" of Ralfs. That the small valves from Oran and Virginia, and the large ones from Cuxhaven, etc., are one and the same species is fully recognised, however, by Rattray, but he names them *A. moniliformis*. To any one who reads carefully Ralfs' account of *A. Ehrenbergii* there can be no possible doubt as to the identity of the species. It was established specially to include the many-rayed forms described by Ehrenberg, which mostly occur at Cuxhaven; Ralfs also states that it is "very fine in Ichaboe guano," and that most of the forms can be obtained therein; and further, that it is "common, both recent and fossil." One species, and only one, answers perfectly to this description, namely, that which Rattray calls *A. moniliformis*, but which, in its larger forms, at least, has been recognised by observers generally as *A. Ehrenbergii*. Rattray might have been justified in preferring the name of *A. moniliformis* on the ground of priority, but he has failed to perceive that the forms which he has placed under it are no other than the *A. Ehrenbergii* of authors, and has inexplicably assigned the name *A. Ehrenbergii* to a species (or variety) differing entirely from that described by Ralfs. It is not found at Cuxhaven, nor, so far as is known, in Europe at all; it is far from being common, either recent

or fossil, and it is not found in Ichaboe guano. It is distinguished from the true *A. Ehrenbergii* by its concentrically undulated valves, by its strong iridescence, and by its sharply defined zones of colour under low powers. Its granules are also more closely and regularly arranged, forming over the greater part of the valve a very regular areolation. To distinguish it from the true *A. Ehrenbergii* I propose for it the specific name of *A. rex*. I have only found it in the deposits of Nottingham, Curfield, Atlantic City, and Lyons Creek. Rattray's localities are necessarily unreliable, so far as they are given on the authority of other observers, of whom some at least (Ralfs, for example) were referring to the true *A. Ehrenbergii*, and not this form at all.

Rattray's description of this species, however, requires amendment, especially as regards the contour of the valve. He says that large valves have the centre depressed, and two concentric elevated zones between the centre and the border, while small valves have the centre depressed, and are convex between it and the border. This is correct so far as some of the valves are concerned, but in others the surface elevations and depressions are in the opposite order. Thus in large valves the centre is convex, and there is one elevated zone between it and the border. Evidently the frustule is concentrically undulated *as a whole*, the depressions of one valve corresponding to the elevations of the other. So in the case of the small valves with depressed centre, others, evidently their counterparts, have the centre convex. Some of the valves in my slides are 0·20 mm. in diameter, Rattray's maximum being 0·17.

The largest European species is, according to Rattray, *A. Ralfsii*, of which I have not seen specimens agreeing entirely with Peragallo's description of the type; but among the forms of *A. Ehrenbergii* abundant in slides from Cuxhaven and Ichaboe guano are many which agree with that description in the arrangement of the fasciculi and subulate areas, though not in the brilliant appearance, the very large pseudo-nodule, nor the concentric arrangement of the granules. One has only to read the descriptions of Ralfs, Van Heurck, Rattray and Peragallo to see that no two of these observers agree as to the respective characters of *A. Ralfsii* and *A. Ehrenbergii*, which is not surprising if, as Peragallo states, every intermediate gradation

exists between the two types. This agrees with the views expressed by Grunow, Lagerstedt, and others; it would seem, therefore, that Peragallo is justified in treating *A. Ehrenbergii* as at most a variety of *A. Ralfsii*.

Most species of Actinocyclus have the markings arranged on the same general plan as *A. Ehrenbergii*. The surface of the valve is divided into cuneate areas by a number of moniliform series of granules (the interfasciculate rays), which radiate from the centre, or near it, to the marginal zone. Each cuneate area contains a fascicle of similar moniliform series, but only the central one is strictly radial, and all the others are parallel with it; and as they all stop short of the interfasciculate rays they are necessarily shorter as they approach these rays. The great difference in the aspect of the valves dependent on the small or large number of fascicles has already been mentioned. In the largest valves, where they are most numerous, they are so narrow that they consist of very few series of granules, and the angles which they form with the interfasciculate rays are so small that at first sight it might appear that all the series are truly radial. Such is the structure in the largest valves of *A. Ralfsii*, *A. Ehrenbergii*, *A. Barklyi*, etc., but the markings are just as truly fasciculate as in the smallest forms, though the fasciculi are not so patent. No amount of variation of the kind described, therefore, is in itself of importance in classification.

But great irregularities in the arrangement of the markings prevail, and there is perhaps no other genus in which valves of one and the same species present such different aspects. While one valve may have the interfasciculate rays very distinct, all starting from a circular central ring of granules, and all the series well defined, the next may present at first sight a very different aspect, owing to the denseness of the granulation, and in yet another much of the appearance of regularity may be lost owing to its sparseness. This is especially noticeable in the centre of the valve, where there may be a regular area, with perhaps a few granules in the centre, while in other cases there may be no definite area at all. Usually the interfasciculate rays stop short at a little distance from the centre, but in the small valves of *A. Ehrenbergii* from Oran, as Mr. Rattray points out, they cross each other. Another point of variation is the width of the blank areas along the sides of the interfasciculate rays.

A. fasciculatus Castracane is distinguished by the notable width of these areas, but the character is of no specific importance. *A. Ehrenbergii* often exhibits such areas, and I have seen them in one valve while the other in the same frustule showed scarcely a trace of them. They may even exist on only a part of a valve. So far as Castracane's figures show, there is nothing to distinguish his species from *A. Ehrenbergii*.

A frequent phenomenon in the genus is the occurrence of regular or irregular blank areas crossing the rows of puncta, often in a sub-concentric fashion, and *A. crassus* is a form in which the apparent irregularity of the markings from this cause has been made a ground for specific distinction. Yet both Van Heurck and Peragallo, who admit the species, show by their figures that the markings are as in *A. Ehrenbergii*, except in so far as the granules are obliterated over certain irregularly sub-concentric areas. I find nothing here to warrant the separation of the form as a distinct species.

The interfasciculate rays are also liable to interruptions, and Castracane has described a species—*A. complanatus*—in which they are said to be wanting, though the valve is of the ordinary fasciculate type. I greatly doubt the correctness of this, not merely on a priori grounds, but owing to Rattray's identification of this species with the form distributed by Möller as *A. Ralfsii*. Now the "*A. Ralfsii*" of my Typen-Platte is simply one of the forms of *A. Ehrenbergii* in which the fasciculation is similar to that of *A. Ralfsii*, and which abound in Cuxhaven and Ichaboe guano material. The interfasciculate rays are certainly *not* wanting, though doubtless obscure and irregular in parts. Many otherwise similar valves occur in which there is no noticeable irregularity of these rays.

The general aspect of the valve depends largely on the position and distance of the granules relatively to the others in the same and adjacent rows of the fascicle. In *A. Barklyi* the granules of each row are very close to each other, but not so close to those of the next rows; the rows therefore remain distinct from each other even to the border. In *A. Ralfsii* type and var. *sparsus* the granules of adjacent rows are mostly side by side, so that they form straight lines crossing the fascicles, thus having as a whole a sub-concentric disposition; they are also distinctly separated from each other. In *A. Ehrenbergii* there is much

variation, the granules often forming irregular zigzag lines crossing the fascicles; generally, however, the tendency is for the granules of adjacent series to alternate with each other, and also to be somewhat crowded, so as to form a quincuncial arrangement, which in any case prevails towards the border. In *A. rex* the alternate arrangement is much more pronounced, and as the granules are crowded equally all round the markings form a very regular areolation over the greater part of the valve.

The appearance of the granules themselves varies remarkably in the same species. In *A. Ehrenbergii* some valves show them in the best focus as minute, dark, sharply defined circles, while in others they are more pearly, and show, much more readily, a central black spot. When crowded, especially towards the border, they form a distinct areolation. In *A. rex* the latter type predominates, but near the centre the granules are more pearly. In *A. Barklyi* and *A. ellipticus* they vary much as in *A. Ehrenbergii*. And in all these species they appear sometimes as dark, well-defined puncta. Peragallo has figured a form which he calls *A. nebulosus*, and which is practically a hyaline valve of *A. Ehrenbergii* with fine puncta instead of granules, also a corresponding form with the puncta arranged like the granules of a typical *A. Ralfsii*. He thinks these valves are probably the result of cleavage, of the correctness of which opinion I think there can be no doubt. Corresponding forms of *A. Barklyi* are found in hundreds in slides of that species, often so delicate and colourless that they become invisible on a slight alteration of the focus. How many layers has a valve of *A. Barklyi*? When manipulating one under the microscope I saw it divide into three, one extremely thin and hyaline, and another somewhat thicker, but still less robust than the main disc. Here the question of colour comes in for consideration, for it is probable that the colour as well as the appearance of the granules depends more or less on the "state" of the valve—whether it consists of more than one plate for instance, or whether the two plates include a film of air between them. *A. rex* is the most brightly coloured form I have seen, having the colours in sharply defined zones. *A. Ehrenbergii* is usually blue, green, purple, or brown, often showing more than one colour, but *not* in sharp zones. *A. Barklyi* varies much in the same way, but is exceptionally liable

to exhibit a dark, semi-opaque aspect. But all these species usually include forms of the same size, contour and arrangement of markings, but of a soft brown colour, uniform throughout or nearly so, and generally with fine puncta. Are these complete valves, or secondary plates, or primary plates from which the secondary ones have been detached? Some of these brown discs have the silex of the subulate areas so thickened as to appear black under a low power. Valves of *A. Ehrenbergii* with sharply defined granules and clear, distinct subulate areas mostly appear blue under low powers, with the subulate spaces white. Others, such as that described above, from Möller's Typen-Platte, are more commonly green or purple, and show no white streaks, though having large subulate areas, the substance of the valve itself appearing to have a dusky tint. The bright colours of these species can only be seen when dry or mounted in balsam or a similar medium, while in water they are colourless.

No other diatom known to me presents such endless variety of marking as *A. Barklyi*, and occurring, as it does, in such profusion, it is especially suitable for a study in variation. This diatom is of interest as being probably the first to be named in Australia, it having been described by Dr. Coates in the Transactions of the Royal Society of Victoria for 1860, under its present name. Rattray incomprehensibly calls it "*Actinocyclus Barklyi* (Ehr.) Grun.," though he knew that it was named by Coates, and not by either of the authors cited. He quotes a reference to it in the *Q. J. M. S.* for 1861 (wrongly quoted as "Plate CXXXVIII." instead of "Page 138"), but does not refer to Coates' original description. It is distributed by Möller under the name *A. dubius* Grunow. It is one of the largest of the genus (perhaps *the* largest), specimens in my slides attaining a diameter of 0·24 mm., or more than double the maximum size assigned to it by Rattray.

In normal valves the fasciculi are arranged much as in *A. Ralfsii*, but great variety exists in the denseness or otherwise of the granules, which, as in *A. Ehrenbergii*, also vary greatly in sharpness. But it is in individual departures from the normal arrangement that the tendency to variation exhibits itself in such an extraordinary degree. In many cases the markings are interrupted at a uniform distance from the centre, so as to form a ring, and several such concentric rings may exist on one valve,

dividing it into zones. Sometimes the markings are denser on one of these zones than elsewhere. Very often the zones form hyaline bands on which the granules are wanting, and the structure may be further complicated by the addition of radial hyaline bands, *e.g.* two hyaline zones may be joined by a number of equidistant radial hyaline areas so that the space between them is divided into a circular series of sub-rectangular compartments; or a broad circular zone may be filled with hyaline patches of all sorts of irregular shapes. The radial series of granules may be all curved in a spiral fashion (a variation which also occurs in *C. Ehrenbergii*), and I have specimens in which the central portion, as far as the first circular interruption, has the moniliform series all contorted in the most extraordinary manner. As in *A. rex*, etc., the subulate areas may be either darker or lighter than the rest of the valve. There may be a small central area, or the whole centre of the valve may be sparsely and irregularly marked.

I find that in some slides concave and convex valves are mixed about equally, leading to the conclusion that the two forms represent opposite valves, as in *A. rex*, but in other gatherings I find many concave valves to every convex one. Rattray describes the valves as flat in the centre and otherwise convex, but in numerous cases the convexity (or concavity) is uniform throughout.

Asteromphalus.—In this genus the lines which radiate from about the head of the centro-lateral area to the apices of the areolate compartments have been assigned too much value in classification. Whether they originate from a single point, or whether they bifurcate, is absolutely immaterial, and the presence of geniculate bends in their course is, in some species at least, equally unimportant. *A. Hookeri*, which is not rare in one of the "Challenger" Antarctic soundings, illustrates this. The forms with six, seven, eight and nine rays, which represent four of Ehrenberg's "species," also a ten-rayed form, occur in slides which I have prepared from this material, and I find the geniculations of the radial lines very marked in some valves, while others show no trace of them; others again exhibit a mixed condition. A good deal seems to depend on the size of the valve, the geniculate lines being most common in the smaller ones.

Certain species are subject to variation in the outline. *A. Cleveanus*, as figured by Schmidt, has a rather narrow ovate

form, but in mud from Manila it has a broader outline, and I found one valve perfectly circular.

Actinoptychus.—This genus is distinguished by its valves being divided into six or more radial cuneate compartments, which are alternately raised and depressed, the markings also differing (in normal valves) on the elevated and depressed areas. On what we may call, for want of a better term, the *primary areas* (*Hauptfelder* of Schmidt), the coarse markings are usually more robust, and often of different form, from those on the *secondary areas* (*Nebenfelder* of Schmidt); further, the primary areas usually bear a tooth or process near the margin, with, in some species, a radial line connecting it with the umbilicus; while the secondary areas sometimes terminate in a submarginal hyaline band, which is not found in the primaries. The fine striation also is commonly different on the two sets of compartments. The striation is generally fairly uniform within the limits of a species, but the secondary markings, consisting of hexagonal or irregular reticulation, or systems of branching veins, is most variable in its distinctness, and is often wanting. When this occurs it is generally assumed to be the result of the detachment of the separate layer of the valve which is thus marked, but in view of the fact that different valves exhibit every possible degree of obsolescence of these markings, I have no doubt that in many cases they have not been developed.

Among the characteristics to which too much importance has been attached in classification are—the number of areas, the substitution of primary for secondary areas (so that all the areas are alike), the presence or absence of the secondary markings, also of the lines connecting the umbilicus with the processes, and the presence of small variations in the striation. The adoption of these purely artificial distinctions has led not only to the undue multiplication of specific names, but, what is worse, to the lumping together of forms which are by no means closely related.

In several species there are six areas, a number which is rarely, if ever, departed from. Such are the forms composing the group of which *A. boliviensis* is typical. In the majority of species there is no constant number; for example the beautiful *A. Heliopelta*, valves of which usually have six, eight, ten, or twelve areas (constituting Ehrenberg's four species of Heliopelta), while more rarely there are fourteen or sixteen. *A. undulatus*,

the most widely distributed species, is found in most localities with six areas only, yet in some Californian deposits it occurs freely with up to eighteen areas, possibly more.

A. undulatus is a species which well illustrates the tendency of the genus to vary in several directions, but the variations are so numerous and so closely linked, and their relationships so obvious, that they have not been made the basis of so many pseudo-species as might have been expected. I have noted about twenty-five forms sufficiently distinct to admit of their being separated for convenience of cataloguing, but few of them are so characteristic as to constitute definite varieties. In forms of average size, which may be considered fairly typical, the secondary markings are commonly about four in 0·01 mm., while in the var. *microsticta* of Grunow, there may be about seven, and in large forms like *forma maxima* Schmidt, there are only one and a half to two. The reticulation may be either hexagonal or irregular, robust or faint, and sometimes entirely wanting. The sub-marginal processes are said to be sometimes absent; in fact, both W. Smith and Van Heurck appear to regard this condition as typical, but I have not seen specimens without some trace of them. (The obsolete genus *Omphalopelta* comprised the valves with processes.) The processes may be very small, appearing merely as a slight thickening of the border, or may be placed a little farther in, presenting a somewhat irregular keyhole-shaped aspect. In many forms the secondary areas have on their margin a small hyaline patch in the corresponding position to that occupied by the processes in the primaries. On both sets of areas the outermost portion, immediately adjoining the margin proper, usually bears radial lines, being continuations of the boundaries of the last row of secondary markings, which, like the secondary markings generally, are most robust on the primary areas. The rim may be smooth, or may have few or many minute apiculi scattered over it. The puncta which compose the striae of the primary areas are arranged in quincunx, so that the striation is the same as in *Pleurosigma angulatum*, but those of the secondary areas form two sets of diagonal striae cutting each other at right angles, as in *P. formosum*. Schmidt describes as *A. biformis* valves in which these two sets of striae meet at rather less than a right angle, so that a third set is visible, closer than the other two, and crossing the area transversely.

Some valves which I have seen with this character were in all other respects similar to normal valves of *A. undulatus*, among which they occurred, and I see nothing to justify their separation, the slight divergence from the rectangular arrangement of the striae being no more than is often found in *P. formosum*. Sometimes the striae meet at *more* than a right angle, so that the third set is radial instead of tangential. If Schmidt's species were accepted, this should make another species! The striae are sometimes nearly or quite obliterated on small patches at the outer angles of the secondary areas, and occasionally along the margins; in some forms again they are wanting or represented only by a few scattered puncta on a great part of those areas. The umbilicus varies greatly in size, and may be either hexagonal or may have three concave sides. Much variation exists in the extent to which the areas are inflated, or, in other words, in the depth of the undulations.

A consideration of the variations of this diatom will show how many features there are which, met with in isolated forms, may lead to the undue multiplication of species.

In several species, perhaps in the genus generally, there is a tendency to produce valves in which the secondary areas or "Nebenfelder" are replaced by primary ones or "Hauptfelder," so that all the areas become alike, except in their elevated or depressed condition. Van Heurck has figured such a form of *A. undulatus*—the *forma sexappendiculata*, which he says may co-exist in the same frustule with the normal form. He refers only to the presence of a process on every area, and does not mention that the areas are otherwise modified, which, however, I have always found to be the case. Other varieties of *A. undulatus* exhibit the same tendency; thus the large *forma maxima* found in the Nottingham deposit is accompanied by its "*forma sexappendiculata*," as also is an equally large variety which only differs from it in the strongly apiculate margin. In all these cases the compartments all correspond exactly with the normal primary areas, both in the striation and the coarser secondary markings. There may possibly be varieties with this as the usual condition, as I have found one or two such forms sparsely distributed in material where I noticed no typical valves to which they might correspond.

In *A. Heliopelta* also valves are formed in which all the areas are alike, instead of alternately primary and secondary.

It is to be noted that in all species where this phenomenon

occurs it is always the primary area, with its process, which is duplicated; we never see valves with all the areas alike and having the distinctive markings of the secondary ones.

Notwithstanding that it has been recognised that in *A. undulatus* the variation in question has no specific importance, being found, in fact, in frustules otherwise normal, a parallel variation in other cases has been made a ground for the foundation of new species, even by observers as recent as Grunow and Schmidt. Such instances are *A. Janischii* Grun., which, as I shall demonstrate, is only a state of *A. splendens*, and *A. Mölleri* Grun., which is a form of *A. adriaticus* Grun. Van Heurck says of *A. Janischii* that it "se distingue de toutes les autres espèces du genre en ce que la valve a toute juste moitié autant d'ondulations que de divisions, de façon qu'une élévation n'est suivie d'une autre élévation que près du deuxième appendice suivant. Une espèce analogue mais plus petite est l'*A. Mölleri* d'Adelaïde, qui se distingue en outre par sa structure plus délicate et l'absence d'une ligne médiane." This is simply equivalent to saying that each area, instead of each alternate area, bears a process, and it is surprising that the writer did not observe that the character referred to as so exceptional was no other than he has figured in the same plate in the *forma sexappendiculata* of *A. undulatus*.

A. glabratus Grunow and *A. Janischii* Grunow are, in part at least, forms of *A. splendens*, but there is a difference in the relationship which they bear to that species, *A. glabratus* simply consisting of valves wanting the secondary markings, while *A. Janischii* is an internal disc. *A. splendens* commonly has a distinct secondary layer showing more or less branching venation, with the typical distinction between primary and secondary areas, but a gathering usually includes a proportion of valves in which the secondary layer is wanting; and although there is every possible gradation, the smooth valves have been described as a doubtful species, under the name of *A. glabratus*. Also accompanying them are valves in which all the compartments bear processes, and to these the name *A. Janischii* has been given, Janisch having figured one of them (as *Halionyx vicenarius*) in his paper on diatoms from guano. In Peru guano *A. splendens* is one of the commonest species, and the typical valves, with their *glabratus*-forms and *Janischii*-forms, are readily obtained. In a Cuxhaven gathering I also find all three forms together. And in a slide of Thum's,

which contains a very robust variety, all three forms are similarly associated. In the valves described as *A. Janischii* the marginal sculpture differs somewhat from that proper to *A. splendens*, but this is a necessary concomitant of the substitution of primary for secondary areas. In *A. splendens*, as in several other species, the secondary areas terminate in a submarginal hyaline band, which encroaches slightly on the primary areas at each side of it. When, however, all the areas have the same structure, this band is wanting, all except the small portion which properly belongs to the primary areas, so that a small rounded hyaline patch opposite the edges of the compartments is all that remains.

The relationship between these forms has always appeared to me obvious, as it evidently did to Ralfs, who describes *A. splendens* as having a tooth on each compartment, or sometimes only on alternate compartments. In order to obtain actual proof of this, however, it occurred to me to examine some Peru guano cleanings which had furnished numerous slides, but in which the complete frustules of *A. splendens*, where they occurred, had been left. I picked out ten of these and mounted them in balsam, with the result that I found that three out of the ten contained valves of the so-called *A. Janischii*, each being included in a frustule between two of the normal valves. In all cases where I have examined whole frustules of *A. splendens* I have found that the two valves were either alike in the number of areas, or one valve had a pair more than the other. Thus, if one valve had sixteen areas it could be predicated that the other would have fourteen, sixteen or eighteen. Where an internal disc was found (*A. Janischii*) it had the same number of areas as one of the outer valves. In the slide referred to one frustule had the outer valves with fourteen and sixteen areas respectively, and the internal disc with sixteen; another had the outer valves with sixteen and eighteen, and the inner with eighteen; and the third had twenty throughout. The areas of the inner disc have the processes rather smaller than those of the outer valves, and nearer the margin. Though the inner disc is usually smooth, like the so-called *A. glabratus*, this is not invariably the case. I have a specimen covered with reticulations as distinct as in the typical valves.

In Van Heurck's opinion several genera, as well as species, have been founded on mere internal valves of various species of *Actinoptychus* (as also of *Asterolampra*). Such are *Debya* and

Gyroptychus, *Debya* being an internal disc of *A. undulatus*, very unlike the outer valves, and found by Van Heurck inside the normal frustules. The *A. pellucidus* Grunow, figured in Van Heurck's synopsis, Pl. 123, fig. 1, is, as will be obvious to any one who compares it with the figure of *A. Heliopelta* in the same plate, merely a valve of the latter with the border wanting and the secondary reticulation undeveloped. In a genus-slide by Thum I have several such valves, but for the most part they retain a little more of the border, showing the origin of the spines, and some of them also have the secondary markings more or less distinctly indicated.

In many marine gatherings from Port Phillip a form of *A. adriaticus* is found in great profusion, of which a specimen is figured in Schmidt's Atlas, Pl. 153, fig. 14. It varies greatly in the distinctness or otherwise of the secondary markings, and especially in the presence or absence or fragmentary condition of the narrow radial lines which in the typical *A. adriaticus*, as in *A. splendens*, run outward from the umbilicus, or near it, to the processes. In most slides a few specimens may be found with all the areas alike, and a process on each, and it is this form which has received the name of *A. Mölleri* Grunow.

Normally the areas are arched at the ends, as shown in Van Heurck's figures, the secondary ones being shorter than the primary, with a wide hyaline band outside them, but as in the form called *A. Mölleri* they are all primary areas, and consequently of the same length, the hyaline band is reduced to a small triangular area at the junction of every two compartments with the margin. All the variations of marking which occur in the normal valves are found equally in this form, and their specific identity is obvious. In reality, this so-called *A. Mölleri* is the true *A. adriaticus* described by Grunow, his original figure showing a valve with processes on *all* the areas, and exactly the same marginal sculpture as described above. It is true *A. Mölleri* is supposed to be without the radial lines to the processes, but Grunow recognised in his original description of *A. adriaticus* that these lines might be present or not, in which he was certainly correct.

These radial lines, however (sometimes called pseudo-raphes), appear to be considered by Van Heurck as distinguishing *A. adriaticus* from *A. vulgaris*, though he admits a possible exception in *A. adriaticus* var. *pumila*. In the common Australian form, however, it is obvious that the presence of

these lines has no specific or varietal significance whatever. Almost every gathering shows valves both with and without them, and innumerable specimens exhibit an intermediate condition, *i.e.* where the lines are more or less broken, or where they are present on some of the primary areas of a valve and not on others. They are scarcely ever complete, but generally stop short of the umbilicus, as in the var. *balearica*. Valves without them are otherwise identical with those possessing them, having exactly the same range of variation in other respects, and this applies equally to the so-called *A. Mölleri*.

While reliance on such characters as the foregoing leads to the improper separation of allied forms on the one hand, it tends in other cases to the opposite error. Thus several varieties of *A. glabratus* have been described, and while some are, as beforementioned, only smooth valves of *A. splendens*, there are others which, so far as I know, cannot be identified with any special form of that species, and which may probably be themselves entitled to specific rank. *A. vulgaris* also, as generally understood, includes forms which have really no close relationship. One such form is nothing but *A. undulatus*, as it is found in Redondo Beach and other deposits, with mostly fourteen areas. The deposit mentioned contains numerous valves of the ordinary form, with six areas, a few with eight, ten and twelve, a good many with fourteen and a few with sixteen and eighteen. The structure of these is absolutely identical with that of the six-rayed forms, and it is as absurd to separate them as it would be to separate forms of *A. Heliopelta* with six areas from those with more. Other forms commonly ranked under *A. vulgaris* are simply valves of *A. adriaticus* with the pseudo-raphes wanting, as already described, while others seem to be similar, but with deeper and more abrupt undulations. The undulations in *A. adriaticus* are very shallow, so much so that Grunow originally described it as flat; but in view of the considerable variation in this respect found in the valves of *A. undulatus* and other species, the character would seem to be of doubtful importance.

Probably the nearest approach to a really flat condition is found in the three-sided *A. marylandicus*, in which the six areas show a very slight difference of level near the centre only, elsewhere blending with each other imperceptibly. This species has a more or less distinctly three-sided umbilicus, and appears to be identical with the *Symbolophora trinitatis* of Ehrenberg. Ralfs has argued against this view on the ground that *S. trinitatis* is

circular, while *A. marylandicus* is three-sided, but in Atlantic City slides valves of the latter species are found in which the divergence from the perfectly circular form is scarcely perceptible, so the objection falls to the ground.

It is sometimes stated as a character of the genus that the depressions of one valve correspond to the elevations of the other, so that the frustule is radially undulated as a whole. That this is not always the case is evident from the fact that the two valves have often a different number of areas. But I find on comparing a number of species that there is considerable variation in regard to the undulations. First we have forms in which the undulations extend to and include the rim itself, so that one valve necessarily fits into the other. A striking example is *A. trilingulatus*, in which the whole valve is so strongly undulated that only three points of the margin can be seen at any one focus. Then we have such species as *A. undulatus* and *A. Heliopelta*, in which the undulations do not extend outward to the margin. Apart from the border itself, the sub-marginal zone is about on a level throughout, but the one set of areas is inflated as much above that level as the other is below it. The border itself slopes down rather steeply, but the depressed areas often reach as low a level as the extreme margin. Still, the width of the hoop ensures that such valves may be placed with the depressions opposite each other without coming into contact. Lastly, in *A. splendens* the depressions do not reach as low as the margin, while the elevations rise considerably above it; even with a narrow hoop, therefore, there is no question of the depressed areas of opposite valves clashing.

According to the definitions of Ralfs and Van Heurck, a character of the genus is the division of the valve into *equal* cuneate segments, which would exclude from it the *A. hispidus* Grunow (Van Heurck, *Synopsis*, Pl. 123, fig. 2), a species which is described as having narrow elevated compartments alternating with wide depressed ones. I believe, however, that the so-called elevated compartments of *A. hispidus* are not compartments at all in the same sense as those of *Actinoptychus*; neither are they elevations, but only appear so owing to having depressions on each side of them. The valve is a shallow cone, by far the greater part of which is occupied by about eight or nine broad radial cuneate areas, *all* of which are depressions. The linear rays or ridges are simply parts of the surface not included in the depressions, but dividing them. These rays slope down evenly

from the umbilicus and join the sub-marginal zone without any interruption of the structure, which indeed is similar all over the valve, except the narrow hyaline border. The valve is very thin, covered with very delicate striae, crossing each other obliquely, and most easily seen on the narrow rays. The secondary markings consist of a fine, delicate, irregular reticulation, at the angles of which are dark points or apiculi, which are larger and darker on the narrow rays and sometimes round the inner border. On each of the linear rays, near the border, is a minute process. In Grunow's figure both the cuneate areas and the dividing rays are abruptly truncate at the border, but my specimens do not agree with this, as the narrow rays widen out in a regular curve towards the border zone, with which they are continuous, the cuneate areas having of course their outer corners rounded off correspondingly, while they do not quite reach the border. Owing to the thinness of the valve, however, and the depressions being by no means abrupt at the outer ends, this character might often pass unnoticed, unless the valve happens to be lying obliquely, when it becomes more conspicuous. Possibly my specimens, which were found in recent gatherings from Port Phillip, may differ specifically from Grunow's guano specimens, but the late Mr. Comber considered them the same.

I think the characters by which this species is distinguished from all others of the genus are such as to entitle it to at least the rank of a sub-genus, for which I would suggest the name *Radiodiscus*. It is possible, however, that it may be brought under the genus *Actinodictyon* Pantocsek, but I am uncertain of the affinities of that genus, of which I have seen no specimens.

I have a single valve, apparently belonging to *A. hispidus*, which differs in several respects from the usual form. Its depressions are extremely slight, there are no secondary markings and no apiculi, and the cuneate areas terminate in a hyaline band, as in *A. splendens*, etc.; it also has exceedingly narrow lines (pseudo-raphes) on the narrow areas ; the border is wanting. It may be a varietal form, or possibly an internal disc, but its pseudo-raphes and hyaline bands seem to indicate a closer affinity with such forms as *A. adriaticus* than would be inferred from the typical form.

SOME NOTES ON BRITISH FRESHWATER RHABDOCOELIDA—A GROUP OF TURBELLARIA.

By Henry Whitehead, B.Sc.

(*Read January 28th*, 1913.)

Plate 4.

The members of the group Rhabdocoelida are very similar as regards appearance, shape and movements to the Infusoria, though they are generally much larger and their complicated internal structure enables them to be distinguished at a glance. The Rhabdocoelida form a branch of the group *Turbellaria*, to which the larger Planarians found in fresh water also belong. The Turbellaria, in turn, together with the Liver-flukes and Tape-worms, are included in the phylum Platyhelminthia or Flat-worms.

The British marine Turbellaria have been monographed by Prof. Gamble (12), and our President has taken an active part in the study of the land Planarians of Australasia. The freshwater Turbellaria have apparently received but little attention in this country, though Prof. Gamble publishes a list of British species in the Cambridge Natural History (14).

As the larger freshwater Planaria (Tricladida) cannot be regarded as microscopic objects, and are therefore of no special interest to the Club, the writer proposes, in this paper, to deal only with the group Rhabdocoelida.

Von Graff has written two monographs on this group, and has devoted much time to valuable work on anatomical features; and it is chiefly from these sources that the information contained in this paper has been derived.

The writer does not propose dealing in detail with the anatomy, but rather to deal with the Rhabdocoels from a general point of view, emphasising matters of particular interest to the field naturalist.

The freshwater Rhabdocoels vary in size from 1/25th to half

an inch in length. They are generally found in ponds, lakes and ditches, and less frequently in running water. Like many other microscopic inhabitants of ponds, they appear in great abundance at certain seasons of the year and then suddenly disappear.

The body is more or less transparent, slightly flattened, and is provided with cilia. The Turbellaria are remarkable for peculiar secretions given off from the epidermis. These secretions are of two distinct kinds—one a mucous fluid, and the other consisting of very small solid bodies, or rhabdites, which, on coming in contact with the water, produce mucus. Several forms of rhabdites have been described (spindle-shaped, rod-shaped, egg-shaped and spherical). They are formed in special glandular cells which lie beneath the epidermis, and the rhabdites pass to the surface by means of minute ducts.

Another interesting feature is the presence, in certain species, of nematocysts similar to those found in Hydra.*

The Rhabdocoels are provided with a mouth, a pharynx and an unbranched, sac-like gut. The position of the mouth varies and affords a valuable generic character. It may lie at the extreme anterior or in a median position anywhere along the ventral surface as far down as two-thirds of the body length.

The excretory system consists of renal organs which are, in some cases, somewhat complicated in structure.

The nervous system is simple, and comprises a two-lobed brain and a pair of nerves running along the body close to the ventral surface. In some species the pigmented eyes are clearly defined, in others the eye pigment is scattered, and in some cases eyes are absent.

Some of the freshwater Rhabdocoels have at their anterior end pit-like depressions which contain cilia (Pl. 4, fig. 3, *cp*). The ciliated pits rest upon a group of ganglion cells which are connected with the brain. Similar structures are found in Nemertine worms, and some zoologists consider that this suggests affinity between the groups. Another interesting organ is the statocyst, which is present in some species. This consists of a cavity containing fluid, in which is suspended a highly

* Mr. Scourfield has recently called my attention to a paper by C. H. Martin (20) on this subject. The author shows conclusively that the nematocysts are derived from the prey upon which the Turbellarian feeds.

refractive particle of calcium carbonate—the otolith (or statolith). The statocysts serve as organs of equilibration.

Reproduction is, in most cases, sexual. The animals are hermaphrodite, but the male organs ripen first. The sexual organs are very complicated, and the details of their structure are of great value in classification. On this account it is often impossible to determine the species of immature individuals, and sometimes it is necessary to have specimens in both the male and the female stages before identification can be certain. Freshwater Turbellaria undergo no metamorphosis, and newly hatched individuals are similar to their parents in general appearance.

Asexual reproduction occurs only in the section Hysterophora. A chain of individuals is formed by the development of mouths, eyes, etc., at intervals along the body. Constriction of the body and gut then follow, and fresh individuals are produced by fission. The process is illustrated in Pl. 4, fig. 3. Some species which reproduce asexually throughout the year develop sexual organs in the autumn. These produce eggs which lie dormant through the winter.

Considerable interest has recently been aroused in certain green or yellow cells which are found in the bodies of some species of Turbellaria. The green cells contain chlorophyll and are able to decompose carbon dioxide in the presence of sunlight. Two marine species, *Convoluta roscoffiensis* and *C. paradoxa*, found on the coast of Brittany, have been the subjects of detailed study, and the results have been summarised by Prof. Keeble in a little book entitled *Plant-Animals*. The genus Convoluta belongs to a group of Turbellaria, the members of which have not, up to the present, been found in fresh water. The green cells or zoochlorellae, as they are termed, are now regarded as algae similar to Chlamydomonas. In the case of Convoluta it is certain that the presence of zoochlorellae is of benefit to the Turbellarian, and that the relationship is a true symbiosis.

Von Graff (17) mentions twenty-five species of freshwater Rhabdocoels in which green cells have been found. The freshwater species containing zoochlorellae have not been well studied, and some zoologists doubt whether there is mutual benefit in the association. This aspect of the subject will, however, be dealt with later.

The Rhabdocoelida live under various conditions, but generally

prefer still or gently flowing water to rapid streams. One species, *Prorhynchus stagnalis*, is sometimes found on moist earth. Many of the aquatic forms are free swimmers, and may be captured in the net in the same way as rotifers and water-fleas; others live in mud. In the latter case it is best to pour a little of the mud into a glass tank containing clear water, and to remove any Rhabdocoels by means of a pipette. They should be examined in a live box, and it will be found that a slight pressure is necessary to ensure making out their internal structure. They are very difficult to prepare in a satisfactory manner as permanent objects, and the writer has made numerous experiments with a view to narcotising them, but with little success. Eucaine, chloroform, ether and alcohol are of no use. The difficulty seems to lie in the fact that the rhabdites are discharged as soon as the animal is irritated, and these, of course, produce quantities of mucus. Moreover, the epidermal cells get destroyed during the process. The only satisfactory method of killing seems to be by means of some hardening reagent, like corrosive sublimate solution, which takes effect before the mucus and rhabdites can be discharged. The following well-known method is the best. The specimen is placed in a watch-glass with a little water, the bulk of which is withdrawn by a pipette. A drop of Lang's Fluid is then delivered from a pipette on the side of the watch-glass and is allowed to run over the animal. Death is almost instantaneous, and but little shrinkage takes place. Even with this method the writer has not yet succeeded in killing species of Mesostoma without disruption. After remaining in Lang's Fluid from ten to fifteen minutes, the specimens are removed to 45-per-cent. spirit. They are afterwards passed through alcohol of increasing strength, stained with borax-carmine and mounted in Canada balsam in the usual way.

Some of the Rhabdocoels appear to be entirely vegetarian in diet, and consume desmids, diatoms and unicellular algae. In fact, care is sometimes necessary to distinguish the food from the zoochlorellae. The latter, however, never occur in the gut. The majority of species take animal food, which consists of water-fleas, small worms, etc.

We may now consider a few typical species which have been taken by the writer in the neighbourhood of London.

Catenula lemnae (Ant. Dug.).

Occurs in ponds and lakes, and often appears suddenly in considerable numbers in collections of rain-water during the spring and summer, and disappears as rapidly as it comes. It is white and thread-like in appearance, consisting of a chain of 2—4 individuals (rarely more) and attaining a length of 5 mm. The body possesses a well-defined head lobe, which is marked off by a slight constriction and a ring of comparatively long cilia; a statocyst is present. The usual mode of reproduction is by fission, but sexual organs are developed when the pond or ditch begins to dry up.

Microstomum lineare (Müll.) (Pl. 4, fig. 3).

This species is very similar to the foregoing, but the colour is yellowish or greyish brown. It is usually found in the form of a chain of zooids of which there may be as many as 18. The colony attains a length of 8 mm. Each zooid develops a pair of red eyes, behind which may be seen the ciliated pits. The skin is thickly clad with cilia. No rhabdites are present, but nematocysts, similar in form to those of Hydra, are present (**20**). The figure shows the manner in which new individuals arise, and various stages in the formation of mouths may be seen. The gut is common to all the zooids in the chain, until fission takes place. The writer has seen desmids which had been swallowed for food pass along the common gut from one zooid to another. Sexual organs are sometimes produced, and the ripe eggs are oval in shape and orange or dark red in colour.

This species is fairly common in stagnant or slowly moving water. It has been found in thermal springs at a temperature of 130° F. and also in brackish water. It moves slowly on a surface, but is a graceful and swift swimmer.

Dalyellia viridis (G. Shaw) (Pl. 4, figs. 1 and 2).

Examples of this species attain a length of 5 mm., and are generally spinach-green in colour. The colour is due to the presence of algal cells which lie beneath the epidermis. The body is truncated in front, widens towards the middle and then tapers towards the tail. There are two bean-shaped eyes. There is a very distinct pharynx and the gut is sac-like.

Specimens of this interesting Rhabdocoel were taken in one of the ponds in Richmond Park, on the occasion of the Club's visit on April 13th, 1912. The following week the writer took specimens from a pond near Chigwell Row, Essex.

It was noticed that the animals had a number of eggs (in one instance 49 were counted) in the spongy body tissue, and individuals in this condition avoided the light. As far as could be ascertained, no eggs were deposited by the living animals, but, on death, the eggs were liberated on the decomposition of the body of the parent. So far none of these eggs have hatched.

Prof. Sekera (16) of Tabor, Bohemia, succeeded in keeping specimens alive for some time, and the following notes are taken from the account of his observations. Young specimens were taken in ponds in March, when ice was still floating on the water. The animals were colourless, but as soon as they approached maturity, and the sexual pore developed, it was noticed that a few algal cells (zoochlorellae) had entered the body cavity by this means. Streaks of green granules then began to spread from this region and extend beneath the cuticle over the whole body, until finally the animal became quite green. (I would remark, in parenthesis, that mature specimens show distinct lines or bands devoid of zoochlorellae.) Solid food in the form of diatoms, rotifers, etc., was ingested during this period. While rapid division of the algal cells was taking place, they formed spherical or ellipsoid clusters, each group being surrounded by a colourless membrane. The membrane finally disintegrated and the algal cells were dispersed in narrow irregular lines or bands. The mature zoochlorellae showed no signs of an enveloping membrane. The animals exhibited at this period a distinct tendency to crawl towards light (phototactic), but sank to the bottom of the vessel at night. During the third week eggs were formed in the body cavity. The worms at this stage began to avoid the light and spent the whole day at the bottom of the vessel or under vegetation. During the first week in May the animals died off rapidly, and with the decomposition of the body the eggs were liberated. The algal cells were set free and continued to live, and developed an investing membrane, then passed into a resting stage, probably awaiting an opportunity of invading the next generation of Dalyellia.

Prof. Sekera thinks that the alga is of little or no value to the

animal in the way of providing food, his reasons being that closely allied species, living under similar conditions, do not contain algae, and that solid food is ingested after the algal cells are fully developed. The writer hopes to investigate this question more fully, for Sekera's argument does not seem to be quite conclusive.

Sir J. G. Dalyell (**1**) wrote an account of this interesting species in 1814, and states that it sometimes occurs in large numbers, and then suddenly disappears. He found his specimens chiefly in the spring, but some were found in the autumn.

Mesostoma Spp. (Pl. 4, fig. 4).

Some of the species of Mesostoma produce two kinds of eggs—thin-shelled and thick-shelled. The thick-shelled eggs, which contain a large quantity of yolk, are produced in the late summer and lie dormant during the winter. The young hatched from these so-called "winter" eggs, when less than half the size of the parent commence to produce thin-shelled eggs with but little yolk. It is probable that these eggs are unfertilised; they are produced in great numbers and begin to hatch in April and May. The young hatched from these eggs attain full development and produce thick-shelled "winter" eggs, which have been fertilised (**14**).

There is some difference of opinion amongst observers as to the precise nature of the life-cycle in this genus. See von Graff (**17**). They vary in size from 3 to 15 mm. in length according to the species and condition. They live in clear, still or slowly flowing water and swim or creep over water-plants. Their food consists of entomostraca, small worms, etc., which are sometimes caught by means of slime threads.

Bothromesostoma personatum (Schm.).

Specimens of this species attain a length of about 7 mm. and are easily identified by two white patches which look like large eyes on each side of the "head." The rest of the body is either grey or black. The writer has taken specimens on the leaves of water-lilies and creeping on the surface film, at Staines and at the East London Waterworks. The genus Bothromesostoma is closely allied to Mesostoma, and like the latter produces both summer and winter eggs.

Gyratrix hermaphroditus Ehrbg. (Pl. 4, fig. 5).

This species appears to be widely distributed. It is about 2 mm. in length, is almost transparent and is a rapid and graceful swimmer. It can easily be recognised by the comparatively long stiletto at the posterior extremity. This weapon, although connected with the male copulatory apparatus, is furnished with a gland which probably secretes a poison of some kind and is used by the animal when attacking its prey. It has a well-marked proboscis, behind which are two eyes. The mouth and pharynx are situated near the middle. As a general rule, only one egg-capsule is present, and this produces one or two embryos.

The field is almost unworked as regards this country. Von Graff records 110 species of Rhabdocoelida from Germany. As far as the writer can ascertain, only 30 species have been recorded from the British Isles. It is hoped that this short account may arouse the interest of some of the members of the Quekett Microscopical Club in these interesting animals.

List of British Species.

In the following list the descriptions of the species will, unless otherwise stated, be found in *Die Süsswasserfauna Deutschlands*, Heft. 19. The initials H. W. after the localities denote that the species has been found by the author at those places:

Sub-order **RHABDOCOELA.**

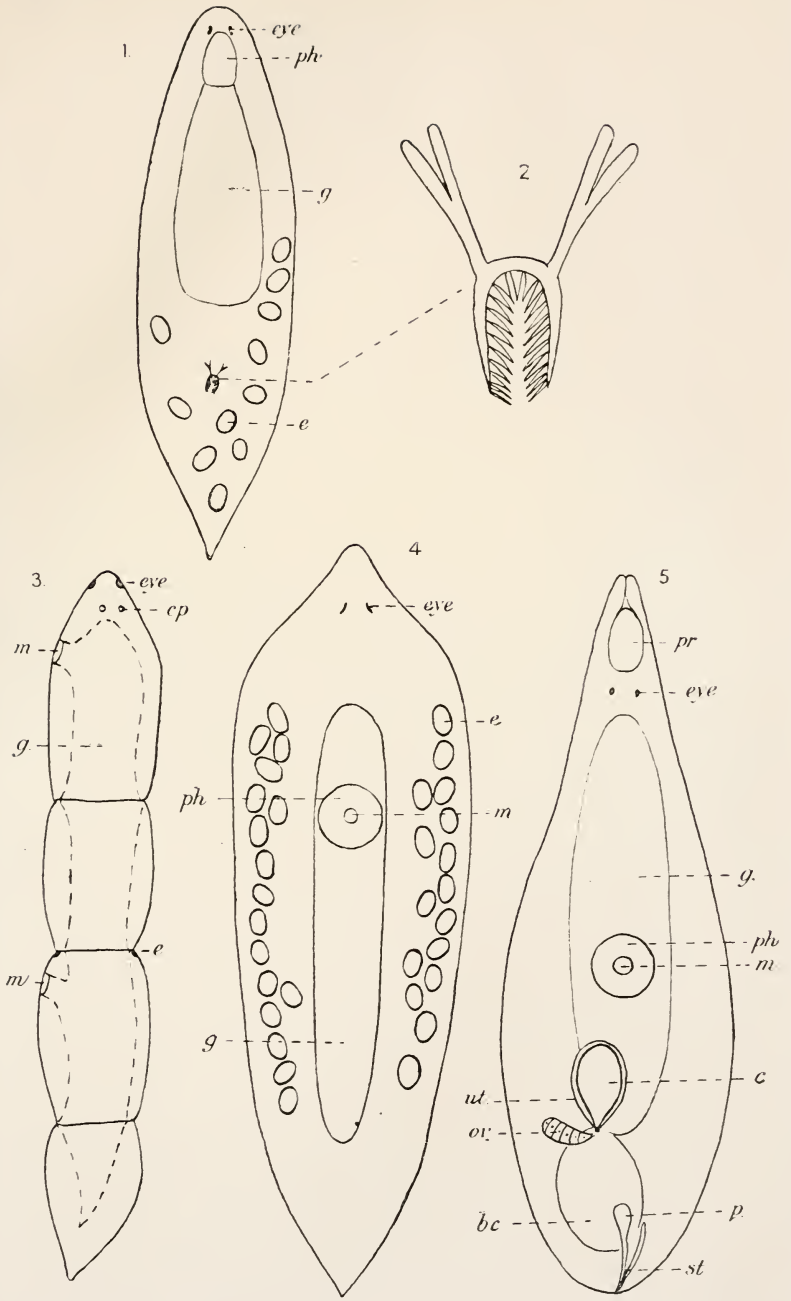
Section Hysterophora.

Fam. CATENULIDAE.

Catenula lemnae Ant. Dug.
Near Cork (**14**).

Stenostomum leucops (Ant. Dug.).
Common (**14**); Clare Is. (**24**); Staines (H. W.).

S. unicolor O. Schm.
Clare Is. (**24**).



H.W del.

RHABDOCOELIDA.

Fam. MICROSTOMIDAE.

Microstomum lineare (Müll).
Fresh water (14): Chigwell: Higham's Park, (H. W.); "In all Scottish lochs" (19); near Dublin (21).

Macrostomum appendiculatum (O. Fabr.) (= *hystrix*, Oe).
Stagnant water (14); Clare Is. (salt water) (24).

Fam. PRORHYNCHIDAE.

Prorhynchus stagnalis M. Schultze.
In Devonshire rivers (14); L. Lomond (19); Fenton Tower, E. Scotland (9).

P. curvistylus M. Braun.
Near L. Lomond (19).

Section Lecithophora.

Fam. DALYELLIIDAE.

Dalyellia diadema Hofsten (18).
Chigwell Row (H. W.). This species appears to have been recorded only once before, viz. in the Bernese Alps.

D. viridis (G. Shaw) (= *helluo* Müll).
Generally distributed (14); Richmond Park, Chigwell Row (H. W.); Edinburgh (9).

D. armigera (O. Schm.).
Millport (14).

D. Schmidtii (L. Graff).
Millport (14).

D. millportianus (L. Graff) (9).
Millport (9).

Jensenia agilis Fuhrm (= *serotina*, Dorner).
Richmond Park, Epping Forest (H. W.).

J. truncata (Abildg.).
Abundant in fresh water (14), L. Lomond (19).

Phaenocora (= *Derostomum*) **punctatum** Örst.
Theydon Bois (H. W.); Edinburgh (9).

Opistomum Schultzeanum Dies.
L. Lomond (19).

FAM. TYPHLOPLANIDAE.

Rhynchomesostoma rostratum (Müll).
Widely distributed (**14**); Millport, Edinburgh (**9**).

Typhloplana viridata (Abildg.) (= *Mesostoma viridatum* M. Sch.).
Manchester (**14**): Clare Is. (**24**).

Mesostoma productum (O. Schm.).
Cambridge (**14**).

M. lingua (Abbild.).
Cambridge (**14**).

M. Ehrenbergii (Focke).
Cambridge (**14**).

M. tetragonum O. F. M.
Cambridge (**14**).

M. Robertsonii L. Graff. (**9**).
Millport (**9**).

M. flavidum L. Graff. (**9**).
Millport (**9**).

Bothromesostoma personatum (O. Schm.).
Preston (**14**); Staines, E. Lon. Waterworks (H. W.).

FAM. POLYCYSTIDIDAE.

Polycystis Goettei Bresslau.
Nr. Abergavenny, L. Lomond (**19**).

FAM. GYRATRICIDAE.

Gyratrix hermaphroditus Ehrbg.
Common in fresh water (**14**); Chigwell Row (H. W.); St. Andrews (salt water) (**9**); Clare Is. (salt water) (**24**).

SUB-ORDER **ALLOEOCOELA.**

FAM. OTOPLANIDAE.

Otomesostoma auditivum (Pless.) (= *Monotus morgiensis* et *relictus* Du Plessis).
Deep waters of Scottish lochs (**19**).

Fam. BOTHRIOPLANIDAE.

Bothrioplana sp.?

Manchester (**14**).

Euporobothria bohemica (Vejd.).

Tarbet, L. Lomond (**19**).

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Description of Plate 4.

Fig. 1. *Dalyellia viridis*, entire, × 15.

„ 2. Chitinous copulatory organ of *D. viridis*, × 150.

„ 3. *Microstomum lineare*, entire, × 20.

„ 4. *Mesostoma* sp., entire with thin-shelled eggs, × 20.

„ 5. *Gyratrix hermaphroditus*, entire, × 45. *b c*, bursa copulatrix; *c*, cocoon; *c p*, ciliated pit; *e*, egg; *g*, gut; *m*, mouth; *o v*, ovary; *p*, poison-sac; *p h*, pharynx; *p r*, proboscis; *s t*, stiletto; *u t*, uterus.

THE ROTIFERA OF DEVILS LAKE, WITH DESCRIPTION OF A NEW BRACHIONUS.

By Charles F. Rousselet, F.R.M.S.

(*Read January 28th*, 1913.)

Plates 5 and 6.

Devils Lake, the largest body of water in North Dakota, U.S.A., is approximately 30 miles long by $5\frac{1}{2}$ miles wide at its broadest part, and of very irregular shape. It receives its water from a territory which forms an inland drainage basin extending northwards as far as the Turtle Mountains.

From the records it appears that the level of the lake has fallen 14 feet since 1883 (when it stood at 1,439 feet above sea-level) and 16 feet between 1830 and 1883, making a total recession of 30 feet in eighty years with a corresponding shrinkage of the area of the lake. At the time of its highest level the lake had an overflow outlet at its eastern end into Stump Lake lying further east, and it is probable that this high-water level was reached many times in past centuries through periods of scanty rainfall succeeded by periods of unusually abundant precipitation. In 1910 the level of the water stood at 1,425 feet above sea-level, but fluctuates about 4 feet between very dry and wet periods. The lake has had no outlet for a long period, and as the result of evaporation the water has become brackish, the salinity increasing gradually by concentration, until at the present time the water has a specific gravity of 1·0076 (the sp. gr. of sea water being 1·027).

Besides common salt the water contains appreciable quantities of sodium sulphate and magnesium sulphate, carbonate and bicarbonate, so that it is alkaline as well as brackish, and this no doubt accounts for the very peculiar and remarkable Rotiferous

fauna it contains, which is abundant in numbers but very restricted in species.

Since 1910 a Biological station has been established on the shores of the lake by the Legislative Assembly of the State of North Dakota, under the control of the Biological Staff of the State University.

At the request of Prof. R. T. Young I have at various times examined samples of plankton collected by him in July 1910 and May 1912, and have found therein only the following seven species of Rotifera, the majority of them rare, strange and unusual forms :

Triarthra longiseta Ehrenberg (*a single specimen, possibly accidental*).
Pedalion fennicum Levander. (*Very abundant.*)
Asplanchna Silvestrii Daday. (*Very abundant.*)
Brachionus Mülleri Ehrenberg. (*Few.*)
Brachionus satanicus Rousselet. (*Very abundant.*)
Brachionus spatiosus Rousselet. (*Very abundant.*)
Brachionus pterodinoides sp. nov. (*Few.*)

Two of these forms I have already described as new,* and have now to introduce a third still stranger species.

The single specimen of Triarthra may have been introduced by accident in one of the tubes.

Rotifera are essentially freshwater animals, and brackish or salt water does not suit the great majority of species; this explains the paucity of species living in Devils Lake.

This fact does not militate against the theory of cosmopolitan distribution of the class, on the contrary it confirms it, for *Pedalion fennicum* is known from brackish lakes only in Finland, Egypt, Central Asia, Asia Minor, etc. The presence in the lake of the rare *Asplanchna Silvestrii* suggests that the "Lago di Villa Rica," in Chile, from which it was first obtained, is a brackish lake. Perhaps Prof. Silvestri, who obtained Daday's

* *Journ. Q.M.C.*, Ser. 2, Vol. XI., pp. 162 and 373 (April 1911 and 1912).

material, would be good enough to confirm or disprove this suggestion.

Brachionus pterodinoides sp. nov. (Pl. 6, fig. 1).

This new Brachionus, of which only very few specimens were found, possesses a type of lorica new to the genus, and appears to have done its best to try to deceive the systematic student by making itself look as closely as possible like a Pterodina. For quite a considerable time I was unable to decide whether the animal belonged to the genus Brachionus or Pterodina until I found one specimen with the foot and its two small toes protruding, which decided the question. As will be seen on referring to Pl. 6, fig. 1, the lorica is nearly circular in shape, greatly compressed and flattened dorso-ventrally, and possesses a foot-opening situated just below the middle on the ventral plate, a most unusual situation for a Brachionus, but usual in Pterodina. The dorsal plate of the lorica is greatly extended posteriorly beyond the foot-opening, and under this projecting cover the eggs are carried. The lorica is smooth except anteriorly, where six small ridges mark the continuation of the six frontal spines. The mental edge is a nearly straight line and without indentation. As far as could be made out in the few preserved specimens available, the internal anatomy of this species appears to be normal. In one specimen the wrinkled foot was extended, showing two small pointed toes, as shown in fig. 1*c*. The lateral antennae protrude high up above the middle on each side.

I am greatly indebted to Mr. F. R. Dixon-Nuttall for the three figures giving an excellent idea of the form of this new species and new type amongst the Brachionidae.

Size of lorica, length 285 μ (1/89th inch), width 224 μ (1/114th inch).

Brachionus satanicus Rousselet (Pl. 6, fig. 2).

When describing this species two years ago * I had specimens only which had been obtained in a plankton collection made in

* *Journ. Q.M.C.*, Ser. 2, Vol. XI., p. 162 (1911).

Devils Lake in the month of July 1910, and all these had the shape shown in the figure, with two long, curved and widely separated posterior spines. Last year I obtained from Prof. Young a collection made in the month of May 1912, much earlier in the season, when the weather in North Dakota is still cold and the water chilly. Together with the fully developed forms in this collection I found a much smaller form, with short posterior spines, curved inwards and other unusual features as represented in Pl. 6, fig. 2*b–f*. The six frontal spines and the mental edge are identical with those of the larger specimens, but the shape of the body and the form and size of the posterior spines are very different, and, strangest of all, the foot-opening is situated on the postero-dorsal side of the lorica, a quite unheard-of position in this genus. My first impression was that these were young animals just hatched from eggs, but this is evidently not so, for some specimens were seen carrying their eggs at the base of the foot on the dorsal side, and they were therefore adults reproducing freely. I can only conclude that this represents a case of dimorphism, possibly a winter form which gradually, in successive generations, transforms itself into the larger form with extended and expanded posterior spines. In saying this I do not mean that the smaller forms (Pl. 6, fig. 2*b–c*) can themselves grow into the form of fig. 2*a*, but that their offspring will in a few generations more and more resemble the larger form. Intermediate forms between the two types figured were not seen. In order to follow up this transformation it will be necessary to obtain plankton collections made about twice a month throughout the year, which at present are not available. It certainly is not easy to see how the dorsally situated foot-opening can change into the median posterior position of the larger form, but it is known that in the case of some Asplanchna (*A. amphora*, *A. Sieboldii*) the transition from humped into saccate forms and other changes take place suddenly, from one generation to the next, produced apparently through a change of diet and temperature, as shown by the recent researches of Dr. Arno

Lange * and Prof. Powers.† Should these changes in *B. satanicus* be confirmed, it will be the first record of true dimorphism in the genus Brachionus. Fig. 2*e* and *f* represent variations in the shape of the posterior spines of the smaller form.

Fig. 2*a–f* were drawn from my own preparations by Mr. F. R. Dixon-Nuttall, to whom I am greatly indebted for these accurate and beautiful drawings.

The large form fig. 2*a* measures 408 μ (1/62nd inch), and the small form 250 μ (1/100th inch), in both cases including the posterior spines.

Asplanchna Silvestrii, Daday.

Pl. 5, figs. 1—9.

This fine and rare species was first described by Daday in 1902,‡ and found by him in plankton collections made by Dr. Silvestri in 1899 in the Lago di Villa Rica in Chile. I have not been able to ascertain if this lake is brackish or not, Prof. Daday having no information on this point, but the presence therein of *Pendalion fennicum* seems to make it highly probable, for the latter species has never yet been found in fresh water.

In the collections from Devils Lake I found *Asplanchna Silvestrii* in great abundance, and moreover it presented a marked dimorphism, and even polymorphism, for all gradations from plain saccate forms to fully developed double-humped animals were represented in the same gathering. Pl. 5, figs. 1—4 represent three of the forms. It is not possible for me to say which of these forms appears first, or which is hatched from the resting-egg, and what causes these changes of form. According to the observations of Prof. J. H. Powers, of Nebraska Univer-

* Zur Kenntnis von *Asplanchna Sieboldii*, *Zool. Anz.* Bd. 38, pp. 433–441, November 1911.

† A case of Polymorphism in Asplanchna simulating mutation. *American Naturalist*, Vol. XLVI., 1912.

‡ Beiträge zur Kenntnis der Süsswasser Mikrofauna von Chile. *Termeszetrajzi Füzetek*, 1902.

sity, who has lately published an account of similar changes in *A. amphora* found by him in a brackish pool, it is caused by a change of diet, from vegetable to more substantial animal food, and even cannibalistic fare. Prof. Powers found that the animals hatched from resting-eggs were invariably saccate, and that the humped and larger campanulate forms developed from these.

Asplanchna Silvestrii is a very large and powerful animal, as is shown by its ability to capture, swallow and digest the large and vigorous Diaptomus which abound in this lake; one of these Copepods was seen to more than fill its stomach.

The male was also found; it is humped, but the side humps are not bifid as in the humped female, as shown in figs. 5 and 6; the fertilised resting-egg is represented in fig. 9. The jaws are of the usual type, but are different from those of any other species of the genus, as is shown by fig. 7. The rami are massive, and have a semi-circular cut-out near the tip, which is peculiar; they have also a strong basal hook and median inner tooth. One of the rami, the one on the right side when the basal hooks are uppermost, has a broad flange near its apical tooth; this serves as a stop for the opposite tooth to prevent the two rami overlapping and interlocking.

The prominent lateral humps differ markedly from those of other humped species, such as *A. Sieboldii* and *A. amphora*. In *A. Silvestrii* these are bifid, having a constriction, more or less pronounced, above the middle of the hump, giving it a double rounded outline (fig. 1); on the dorsal side there is a pointed hump near the middle of the body (fig. 2). In intermediate forms the humps are less prominent until the purely saccate form is reached (fig. 3), which in shape does not much differ from that of *A. Brightwelli*. Prof. Powers has shown that no single animal goes through these various shapes; they are born with the shape they possess and do not change it in their lifetime, but their progeny may have a different shape from the parent. A young humped individual may be seen in

the uterus of a saccate female. The change takes place more or less suddenly from one generation to the next. The general anatomy of *A. Silvestrii* follows that of other allied species, and but few points need be mentioned. The two gastric glands are large and kidney shaped, and are attached to the long and rather wide oesophagus. The stomach has the usual structure of large, dark-coloured granulated cells. The ovary has the form of a narrow horseshoe-shaped band with a single row of germ cells. An enlarged view of one of the lateral canals with the contractile vesicle is given in fig. 8. The flame cells are closely set and numerous, numbering over thirty; the fine tube to which they are attached adheres for some distance to the nerve-thread of the ventro-lateral antenna on each side.

The sense organs consist of three pairs of antennae, namely two on the front of the head, two dorso-lateral and two ventro-lateral in position, each ending in a rocket-shaped organ with a tuft of stiff hairs on the outside. Two finger-like, fleshy processes are seen, one on each side of the head close to the corona. Daday mentions that the animal has three red eyes, but I could discover only a single small cervical red eye, situated on the small brain.

The male (figs. 5 and 6) is of usual structure, and has two lateral humps, like the male of *A. amphora.*

Greatest size of female 1,150 μ (1/22nd inch) in length; male 408 μ (1/64th inch); jaws 164 μ (1/155th inch); resting-egg 195 μ (1/120th inch) in diameter.

I am greatly indebted to Mr. Hammond for the excellent figures of *A. Silvestrii* on Plate 5.

It is quite possible that further plankton collections, and particularly collections made amongst the aquatic vegetation near the shores and in the bays of Devils Lake, may reveal additional species of Rotifera, but a great crowd of freshwater forms cannot be expected to inhabit this brackish and alkaline lake.

Explanation of Plates 5 and 6.

Plate 5.

Fig. 1. *Asplanchna Silvestrii* Daday, characteristic female with double humps, dorsal view, × 50.

„ 2. *A. Silvestrii*, side view, × 50.

„ 3. *A. Silvestrii*, saccate form, dorsal view, × 50.

„ 4. *A. Silvestrii*, intermediate form, ventral view, × 50.

„ 5. *A. Silvestrii*, male, side view, × 68.

„ 6. *A. Silvestrii*, male, dorsal view, × 68.

„ 7. *A. Silvestrii*, the jaws, × 217.

„ 8. *A. Silvestrii*, vascular system with contractile vesicle, × 150.

„ 9. *A. Silvestrii*, resting-egg, × 65.

Plate 6.

Fig. 1*a*. *Brachionus pterodinoides* sp. nov., dorsal view, × 196.

„ 1*b*. *B. pterodinoides*, ventral view, × 196.

„ 1*c*. *B. pterodinoides*, side view, × 196.

„ 2*a*. *Brachionus satanicus* Rousselet. Normal type, × 180.

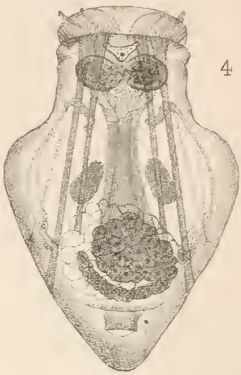
„ 2*b*. *B. satanicus*, small seasonal form (winter), dorsal view, × 180.

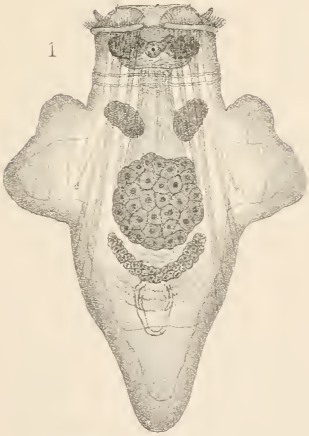
„ 2*c*. *B. satanicus*, small seasonal form (winter), ventral view, × 180.

„ 2*d*. *B. satanicus*, small seasonal form (winter), side view, × 180.

„ 2*e*. *B. satanicus*, small seasonal form (winter), variation in posterior spines, × 200.

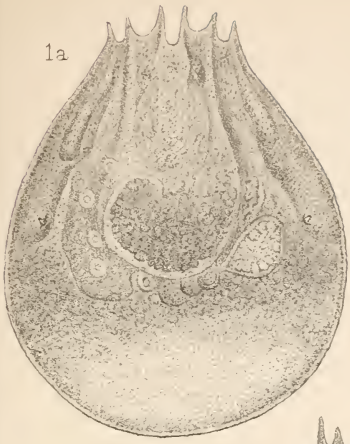
„ 2*f*. *B. satanicus*, small seasonal form (winter), variation in posterior spines, × 200.

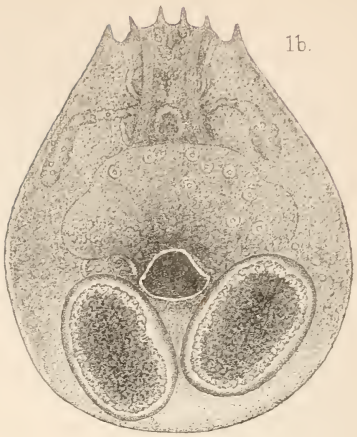


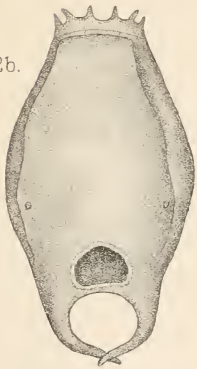


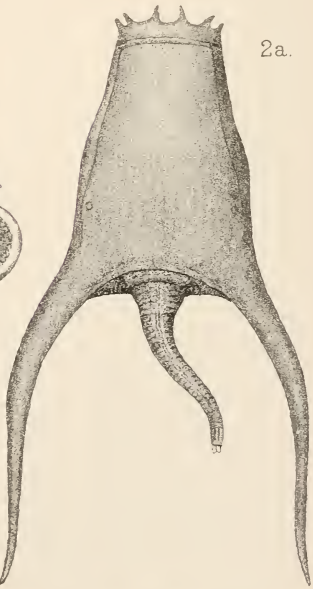
A.R.Hammond del et lith. West, Newman imp.

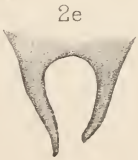
Asplanchna Silvestrii *Daday*











F.R.Dixon-Nuttall del. ad nat.

A.R.Hammond lith.
West, Newman imp.

Rotifera.

THE PRESIDENT'S ADDRESS.

BY-PRODUCTS OF ORGANIC EVOLUTION.

By Prof. Arthur Dendy, D.Sc., F.R.S.

(*Delivered February 25th*, 1913.)

Plate 7.

We are all familiar with the fact that in the manufacture of any particular product of human industry the raw material employed is rarely entirely used up, a more or less considerable residue generally remaining over after the process is completed. In so far as the prime object of the manufacturer is to produce some one special product, the residue which cannot be employed for this purpose must be regarded as waste. It frequently happens that this waste product is a highly deleterious substance, the difficulty in the disposal of which may constitute a very serious obstacle to the successful prosecution of the industry in question. On the other hand, it also frequently happens that what were primarily waste products may prove to have a value of their own quite apart from the main object at which the manufacturer is aiming. They then cease to be merely waste products and become valuable by-products, perhaps even more valuable than the main product itself.

Thus in the distillation of coal in a gasworks the main purpose, that for which the machinery and apparatus are primarily intended, is the production of gas, but coke and tar and other by-products are also produced, all of which are now, I suppose, applied to some useful purpose, and thus have a value of their own. Indeed the existence of coal-tar has given rise to a whole series of new industries, involving the production of almost endless substances, such as the wonderful aniline dyes and so forth, which many people will regard as far more valuable and desirable

objects than the gas for the sake of which the coal was originally distilled.

The value of a by-product will naturally depend upon the particular circumstances of the case, and what is useless, or even harmful, under one set of conditions may be extremely valuable under another. It may be a question of labour supply or of transport, or it may be that the discovery of some new process of manufacture in a totally different industry suddenly creates a demand for a by-product that was previously almost or entirely worthless. It is perhaps not too much to say that the success or failure of a manufacturer in his business must in many cases depend upon the ingenuity that he exhibits in disposing of his by-products; but the formation of such products in the first instance cannot be avoided, and they may go on being produced, and constitute a characteristic feature of the industry for a long time, before some new factor in the circumstances of the case may give them a special value of their own. It may well be that this may never happen at all, and the substances in question may simply accumulate in harmless, if unsightly, heaps, or, on the other hand, they may become so offensive, or even dangerous, as to render impossible the continuance of the industry which gives rise to them.

In short, it would be difficult to exaggerate the importance of the part played by by-products in the evolution of human industries. Such industries are necessarily subjected to a severe struggle for existence in ceaseless competition with one another, and in this struggle the by-products afford abundant opportunity for the elimination of the least fit by the process of natural selection. The by-products, however, did not themselves arise through any process of selection, but as the unintentional and inevitable results of those chemical and physical changes which accompany the manufacture of the main product.

We may thus look upon a human industry as an organism, which undergoes a process of evolution subject to the control of natural selection, and some of the most characteristic features of which are to be found in its by-products. Indeed it may often be recognised and identified by its by-products almost if not quite as readily as by the product for the sake of which it primarily exists.

We must not, of course, push our analogy too far, but I hope to

be able to convince you that in the evolution of living organisms themselves by-products have played a part not unlike that which they have played in the evolution of industries.

You have probably already begun to wonder why I should have chosen such a subject as this for an address to a microscopical club; but the reason will now become apparent, for I propose to endeavour to elaborate the ideas which I have been suggesting to you by reference to organisms which have long been favourite subjects with the microscopist, and to characters which can only be investigated with the aid of the microscope.

We shall perhaps find nowhere in the animal kingdom a more exact analogy to the utilisation of waste products in human industries than in the curious rotifer *Melicerta janus*. As you are all aware, this minute but highly complex organism builds for itself a beautiful dwelling-place out of pellets of its own dung. I do not, however, propose to dwell upon such cases as this, and for our present purposes I must ask you to allow me to interpret the term waste products, or if you prefer it, by-products—for it is obvious that the two cannot be sharply distinguished from one another—in a less literal manner.

There is, in my opinion, no group of organisms better suited for the illustration of the fundamental principles of organic evolution than the Sponges. This arises from the fact that they combine with an essential simplicity of structure an inexhaustible variation in detail, and that this variation is to a very great extent clearly and precisely expressed in the form of the microscopical calcareous or siliceous spicules of which the skeleton is ordinarily composed. Moreover, it appears that an unusual number of connecting links have been preserved to the present day, so that we are able to trace beautiful evolutionary series in the wonderful spicule-forms of existing species.

Take, for example, the siliceous spicules which are so characteristic of the Tetraxonida. These are probably all to be derived from a primitive ancestral form or archetype (fig. 1) consisting of four rays diverging at equal angles from a common centre, like the axes which connect the angles of a regular tetrahedron with its central point. The assumption of this regular geometrical form by a non-crystalline substance like the hydrated silica, or opal, of which these spicules really consist, is a very remarkable

fact, especially when we consider how very widely it is afterwards departed from on most lines of spicule evolution. It has been suggested that the equiradiate and equiangular tetraxon was originally adapted to the interstices in a system of spherical flagellated chambers arranged tetrahedrally. This seems probable enough, but in any case we can safely take this form as our archetype without indulging in speculations as to its origin.

If we now imagine one ray of our archetype becoming greatly elongated we get a common form of "triaene" spicule known as the "plagiotriaene" (fig. 2), with a long arm or "shaft" and three short arms or "cladi," but still with all the angles equal. If we imagine the angles which the cladi make with the shaft to be increased, so that the cladi come to point forwards, we get the "protriaene" (figs. 5, 5*a*); if the cladi extend at right angles to the shaft we get the "orthotriaene" (fig. 3), and if they point backwards we have the "anatriaene" or grapnel spicule (figs. 4, 4*a*).

All these long-shafted triaenes are typically oriented with the cladi at or near the surface of the sponge, and the shaft directed centripetally inwards, so that the entire skeleton acquires a markedly radiate arrangement. The cladi of the orthotriaenes usually form a support for the dermal membrane at the surface of the sponge, beneath which they are spread out tangentially, and their efficiency as a dermal skeleton may be greatly increased by their bifurcation ("dichotriaenes," figs. 6, 6*a*). In the case of the protriaenes and anatriaenes the distal portions of the shafts, bearing the sharp-pointed prongs or cladi, usually project for some distance beyond the surface of the sponge, and in this position they probably serve either to ward off the attacks of enemies or to entangle minute organisms whose decomposition may supply the minute organic particles upon which the sponge depends for its food supply and which will be carried inwards by the inflowing stream of water.

A still more remarkable modification is met with in the "discotriaene," in which the shaft is reduced to a short peg inserted in the middle of a flat disk formed by fusion of the cladi. The entire spicule then assumes somewhat the form of a carpet-nail. In the genus *Discodermia* we find these discotriaenes stuck close together all over the surface of the sponge, and forming an impenetrable mail-armour.

In *Stelletta vestigium*, on the other hand, the cladi are reduced to the merest vestiges, and some, if not all of them, may completely disappear, while the shaft remains greatly elongated and forms practically the entire spicule (figs. 7*a*—7*d*). Possibly the simple "oxeote" spicules of this and allied species (fig. 8) have arisen in this manner.

An altogether different line of evolution from the primitive tetraxon archetype appears to have given rise to the typical oxeote spicules (figs. 9, 10) of the monaxonellid division of the Tetraxonida. Here two of the four rays of the primitive tetraxon have probably entirely disappeared, while the remaining two have become extended in a straight line with one another. In the typical "stylote" (fig. 11) and "tylostylote" (fig. 12) spicules probably only a single ray persists, so that the so-called organic centre is situated at one end instead of in the middle. In many species the oxea, styles or tylostyles become ornamented with sharp spinose excrescences (fig. 13).

In most of the cases which we have so far considered it is easy to see that we are dealing with adaptive modifications. The orthotriaene, dichotriaene, protriaene, anatriaene and discotriaene are all obviously well suited for the fulfilment of their specialised and differentiated functions, and the evolution of these forms is more or less readily explicable in accordance with the well-known principle of the natural selection of favourable variations. The origin of the linear spicules of the monaxonellid forms by complete suppression of two or three of the rays of the primitive tetraxon is, perhaps, not so easy to account for as is that of the triaene series from the same starting-point. In both cases the determining factor was probably, in the first instance, the development of a radially arranged canal-system, requiring a corresponding radial arrangement of the supporting skeleton, which could not be obtained with spicules of the primitive tetraxon form. That the evolution of the necessary linear spicules has taken place along different paths in different cases is, however, nothing to be surprised at; it is merely one of those instances of convergence which are quite as common amongst sponges as amongst other groups of the animal kingdom.

In the most primitive tetraxonid sponges, which represent more or less closely the ancestral forms from which both

Tetractinellida and Monaxonellida have doubtless been derived, we still meet with some of the earliest stages of spicule evolution. Take, for example, *Dercitopsis ceylonica*, collected by Prof. Herdman in Ceylon, and described in my report on the Ceylon sponges. Here we find the tetraxon spicule in all its primitive simplicity (fig. 25), but associated with it we get numerous diact spicules (figs. 26*a*—26*c*), evidently derived from the tetract by loss of two of the original rays, and clearly showing, by a swelling or an angulation in the middle, that two rays still remain. From such obvious diactine spicules as these, transitional forms lead the way to the comparatively large, straight oxeote spicules which occur in the same and in many other sponges, and which no longer show any trace of their tetraxon and tetract ancestry.

In Dercitopsis and its relations—*i.e.* in the Hómosclerophora —although there may be great differences as regards the size of the various spicules, yet we cannot, as in most of the higher groups, sort these spicules out into two distinct categories— megascleres and microscleres—for innumerable gradations exist between large and small.

In the course of further evolution, however, the distinction between megascleres, or skeleton spicules, and microscleres, or flesh spicules, becomes very strongly marked. Both have doubtless had a common origin in the ancestral tetraxon archetype, but whereas the former are obviously adapted as the principal skeletal elements, and are arranged accordingly in the sponge, the latter are usually scattered at random through the soft ground substance like plums in a pudding, and neither in form nor arrangement show any evident adaptation to the requirements of the organism.

Indeed, the microscleres are usually so extremely minute, requiring high powers of the microscope to make out their true form, that is impossible to believe that their presence can exercise any important influence upon the well-being of the sponge. Still less is it possible to believe that the particular shape which they may assume, which is often highly remarkable, can be of any consequence to their possessor. There are, of course, exceptions to this, as to every generalisation, and sometimes we find microscleres forming a dense protective external crust, as in the case of the "sterrasters" of Geodia, or projecting into the

inhalant canals, where they may perhaps serve to filter the incoming water and guard against parasites, as in the case of the "sigmata" of *Esperella murrayi*; but in the vast majority of cases it is impossible to assign any value at all to the presence of microscleres. Indeed, the numerous species of horny sponges seem to get on quite as well without these bodies.

Nevertheless we find that the microscleres, when present, are characterised by very definite and constant forms, and many of them are amongst the most beautiful and wonderful objects that come under the observation of the microscopist. So constant and characteristic are they that they afford by far the most convenient and most reliable data for the classification of the tetraxonid sponges. Particular species, and even particular genera and families of these sponges, are characterised by the presence of highly specialised forms of microscleres, and in the case of species the characteristic form is almost invariable.

There can be no doubt that the microscleres have undergone an evolution along definite lines, and one species of a genus is commonly distinguished from another by differences in the shape of these spicules, which, though constant, appear at the same time to be utterly trivial—as, for example, the difference in the shape of the teeth at the small end of the "isochelae" in *Cladorhiza pentacrinus* (figs. 23, 23*a*) and *Cladorhiza* (?) *tridentata* (figs. 24, 24*a*). There may be several kinds of microsclere in the sponge, all characteristic of the species, but a single sponge may contain many thousands, or perhaps millions, of the same kind, all exactly alike in shape and size except for an occasional individual variation such as occurs in all organisms.

The shape of the microscleres appears to be quite independent of their position in the sponge, and must obviously be attributed to some specific peculiarity of the ovum from which the sponge developed. It is clearly of a blastogenic and not a somatogenic character, and it is usually much more remarkable and quite as constant as that of the megascleres of the same species.

The microscleres of the tetraxonid sponges may be divided into two categories, termed astrose and sigmatose respectively. The former (figs. 14*a*—14*h*) may be derived from the tetraxon archetype by multiplication of the rays—due apparently to meristic variation—accompanied usually by diminution in size of

the whole spicule; at the same time the rays may become spiny or branched in a variety of ways, or even soldered together to form a solid siliceous ball (*Geodia*).

The sigmatose microscleres are more remarkable and more constant in form. They are essentially linear spicules, and appear to be derived from minute diactinal oxea. These may be straight ("microxea," fig. 15) or bow-shaped ("toxa," figs. 16, 18*a*, 18*b*), or their extremities may become bent over to form hooks ("sigmata," figs. 17*a*, 17*b*, 19). A very peculiar modification of the sigmata is found in the "diancistra" (fig. 21), which often resemble nothing so much as pocket-knives with the blades half open. From the sigmata have also doubtless arisen the "chelae," * characteristic of the family Desmacidonidae, and, in my opinion, the most wonderful of all sponge spicules. Three different chelae are shown in figs. 22—24*a*.

A typical chela consists of a curved shaft, bearing a number, commonly three, of recurved teeth, resembling the flukes of an anchor, at each end. The flukes are sometimes expanded into thin blades, and so also may be the shaft. Sometimes the flukes at the two ends of the spicule are equal in size ("isochelae," figs. 22, 22*a*), sometimes those at one end are larger than those at the other ("anisochelae," figs. 23—24*a*), while in the genus Melonanchora a very curious effect is produced by the meeting and fusing of opposite flukes of an isochela at the equator of the spicule. Minute differences in the form and number of the flukes and the shape of the shaft appear to be constant, at any rate within the limits of a species; indeed, the very numerous species of Desmacidonidae are to a large extent distinguished from one another by these characteristics (compare figs. 23, 23*a*, and 24, 24*a*).

The same constancy of form is to be observed in the sigmata, although here there is less scope for specific differences. In both cases the spicule, instead of remaining smooth, may become more or less roughened by the development of minute projections. This is shown, for example, in the sigmata of the genus Paresperella (fig. 20), where a row of small projections, like the teeth

* It is perhaps unnecessary to discuss here the evidence for believing that the chelae have arisen from sigmata. It is derived partly from the development of the chelae themselves and partly from the occurrence of intermediate forms.

of a saw, occurs at each end of the shaft, just where it bends round.

Now it appears to me quite idle to argue that minute differences in the form of the microscleres, such as I have just described, are of any importance to the sponge in whose soft tissues these microscopic spicules are scattered without order or arrangement. Nevertheless they constitute, as I have already said, constant specific characters, and have undoubtedly arisen by some process of evolution, one form leading to another just as in the case of any other characters. Such characters are, of course, by no means confined to sponge spicules; they may be more or less exactly paralleled, for example, in the frustules of Diatoms, the shells of Foraminifera and Radiolaria, and the calcareous spicules of Holothurians. Natural selection cannot be directly responsible for their origin. How, then, are they to be accounted for?

Before attempting to answer this question let us inquire how a microsclere actually arises in the sponge. It appears that, from an early stage in embryonic development, certain cells, known as scleroblasts, or mother-cells, are set aside for the purpose of spicule-formation. These mother-cells have the power of extracting silica in solution from the sea-water which circulates through the sponge, and depositing it in the form of solid opal, and in the particular shape characteristic of each spicule. Each separate microsclere arises thus in the interior of a single mother-cell. Let us examine a little more closely the conditions under which it is deposited.

The mother-cell is, of course, a nucleated mass of protoplasm, and it appears to be bounded on the outside by a more or less definite cell-membrane. The spicule, at any rate in the case of sigmata and chelae, appears to be deposited on the inner surface of this membrane, and this fact probably explains why it is curved. If we assume, as seems probable, that the mother-cell continues to grow while the spicule is being deposited, and that the spicule is adherent to the cell-membrane, then we may further suppose that the increasing tension and expansion of the latter may cause the thin siliceous film to split into flukes or teeth. Probably, then, the form of the spicule is largely due to mechanical causes. We cannot, however, explain the minute details of structure so simply as this, for why should the chela

of one species have always three flukes and that of another always more? Why should the two ends in some cases be equal and in others unequal? Why should the teeth at the small end sometimes be shaped as in fig. 23 and sometimes as in fig. 24? and why should some be roughened with spines and others not? We must, I think, assume that these minute differences are dependent upon minute differences in the constitution of the protoplasm of which the mother-cell is composed. It may be a question of the chemical and physical composition of the cytoplasm in which the spicule is actually deposited, or it may be that the nucleus exerts some direct controlling influence upon the form of the spicule, of the nature of which we know nothing.

At any rate we can hardly be wrong in attributing specific differences of spicule-form to corresponding differences in the constitution of the mother-cells by which they are secreted. The remarkable thing is that such differences should be so constant, not only throughout hundreds of thousands of mother-cells in the same sponge, but throughout the mother-cells of all the individuals of the same species. We can only suppose, as I said before, that this constancy depends upon some constant peculiarity of the germ-plasm from which all the cells of the individual and all the individuals of the species originate. Obviously the fertilised ovum must contain within itself the potentiality of producing, amongst other things, all the different kinds of spicules which may happen to characterise the particular species to which it belongs. As development goes on differential divisions must take place whereby all the different kinds of cells of which the adult sponge is composed are segregated, and each mother-cell must ultimately retain the power to secrete only one particular kind of spicule. Now there is strong reason for believing that differential cell-division is effected always by the complex process of mitosis or karyokinesis, which concerns chiefly the chromosomes of the nucleus, and hence I think we may pretty safely conclude that specific differences in the form of the microscleres must depend upon differences in the constitution of the nuclei of the mother-cells, or, in other words, that the nuclei of the mother-cells determine to a large extent the form of the microscleres.

There appear, in short, to be three secondary factors concerned in the production of any particular form of microsclere: (1) the

nature of the material (opal) of which the microsclere is composed; (2) the nature of the medium in which it is deposited, viz. the colloidal cytoplasm of the cell; and (3) the presence of the cell-membrane, by which the growth of the spicule is to some extent restrained and guided. All three are, however, doubtless dependent upon the hereditary constitution of the mother-cell (including, of course, its nucleus), for while the mother-cells in siliceous sponges secrete hydrated silica, those of the Calcarea secrete carbonate of lime, and so on.

We have next to inquire how it is that, if the specific forms of sponge microscleres are of no importance to the sponge, such very remarkable forms should ever have arisen in the course of evolution. We have to remember in this connection that we are dealing not merely with a few isolated and unrelated forms, but with progressive evolutionary series along lines as definite as any other lines of evolution with which we are acquainted, and which certainly seem to require some directive force to explain them. If we were dealing with adaptive characters we should at once say that the result was due, as in the case of the megascleres, to the natural selection of small, fortuitous, favourable variations; but the fact that the characters in question are, for the most part at any rate, not adaptive, seems, at first sight at any rate, to rule natural selection out altogether.

It might be suggested, however, that the solution of the difficulty is to be found in the well-known principle of correlation. In accordance with this idea certain characters of an organism are inseparably linked together with other characters in such a way that any variation in the one must be accompanied by a corresponding variation in the other, though the reason why such characters should be so linked together is often by no means obvious. To upholders of such a view as this the analogy of by-products, upon which I laid so much stress at the beginning of my address, may, I think, prove useful. Although I doubt whether the hypothesis of correlation is adequate to meet the present case completely, it certainly seems worth while to examine it a little more closely.

I may illustrate my meaning by reference to the action of a few drops of acid upon an alkaline solution of litmus. Two perfectly distinct results will be produced. The solution will become acid and it will change from blue to red. You may desire for

some special purpose to produce one of these results only, but they are inseparably connected and you cannot have one without the other. You cannot have the result aimed at without having also the by-product.

Now suppose some change in the constitution of the germ-plasm of an organism to give rise to two modifications in the developing soma or body. We may call the change or modification in the germ-plasm GA and the modifications in the soma SA and S*a*. SA and S*a* will be inseparably correlated with one another through GA, though—as for example in the case of white tom-cats with blue eyes, which are said to be generally deaf—the connection between them may appear to be quite arbitrary.

Suppose further that SA proves to be a useful character and S*a* a useless one. Then, under the influence of natural selection, SA will be preserved and may ultimately develop into a very perfect adaptation; but, if so, GA must also undergo further modification, and this modification will likewise affect S*a*, which will therefore keep pace, so to speak, with SA. Thus a non-adaptive character (S*a*) may undergo progressive evolution, which, though in reality indirectly controlled by the action of natural selection, may appear to be guided by some mysterious vital force or entelechy.

Now suppose further that as a result of some change in the conditions of life, or merely as the result of its progressive evolution in some particular direction, S*a* in turn acquires some value in the struggle for existence. Natural selection will, in future, favour its further development directly, and what was at first a mere by-product becomes an adaptive character. Thus adaptive characters may perhaps become linked together in groups, the existence of each group being dependent on some particular property of the germ-plasm through which all the members of the group are connected.

At the same time non-adaptive characters may persist side by side with adaptive ones, and even harmful variations may persist if their injurious effects are counterbalanced by useful characters with which they happen to be correlated and which cannot exist without them. Inasmuch, however, as two useful characters are more valuable than one, natural selection will tend to favour the correlation or linking together of adaptive

characters, and this is perhaps the reason why, in the higher organisms, non-adaptive characters are less frequently met with than in lower forms. Moreover, the effect of natural selection will tend to become cumulative and the rate of evolution correspondingly increased.

It may be objected that even in the highest organisms characters often vary independently of one another, but who knows how many characters are really involved in each such variation? Moreover, it by no means follows from what has been said above that new characters, whether valuable or otherwise, may not arise singly and remain quite independent of others.

In any case the principle of correlation could hardly help us to explain the specific forms assumed by sponge microscleres, or indeed the exact nature of any non-adaptive character; it could only help to explain why such characters should exist at all and why they should undergo progressive evolution.

If it be asked, what are the adaptive characters with which, in our own particular case, the non-adaptive characters of the microscleres are supposed to be correlated? it must be admitted that this question cannot—at any rate at present—be answered, but it would be sufficient for the general argument if it were granted that a modification in the constitution of the germ-plasm which gives rise to a useful character may at the same time give rise also to a useless one, or perhaps even to many useless ones.

The question, why are the specific forms of sponge microscleres what they are? is probably one that will have to be answered, if it ever is answered, by the chemist and physicist rather than by the mere biologist; or perhaps by that happy combination of chemist, physicist and biologist whose advent is so much to be desired. I have suggested that the form is probably determined by the hereditary constitution of the mother-cell, including its power to select silica as the raw material to be worked up, but this is no more than to say that the nature of the product turned out by a factory depends upon the character of the work-people employed and of the machinery and raw material with which they have to deal. In the case of our microscleres we want to know a great deal more about the nature of the machinery and the manner in which it is controlled

before we can hope to reach even an approximate solution of the problem.

Some light may perhaps be thrown on the subject by experiments such as those of Leduc and others upon artificial osmotic growths. Leduc, in particular, has succeeded in producing very interesting growth-forms by the osmotic action of various chemical reagents in solution. Some of these forms bear an extraordinary resemblance to the forms of living organisms. I do not, of course, attribute much importance to the particular forms produced in this manner as explaining the particular forms of any living organisms. What they demonstrate is that purely chemical and physical causes may give rise to more or less definite and at the same time non-crystalline forms in colloidal media, and though none of the forms as yet produced come anywhere near our sponge-spicules in symmetry or sharpness of definition, they certainly seem to indicate a hopeful line of inquiry. The particular form produced depends upon the nature of the reagents employed and upon the conditions under which the experiment is carried out. If these always remain constant we may assume that the osmotic growth will always have the same form, but probably with the means at our disposal it would be impossible to produce exactly the same result twice over. The remarkable thing about the sponge microscleres is that within the limits of the same species the same results very often are exactly reproduced, or at any rate so exactly that we are unable to distinguish between them. I suggest that these results are produced by chemical and physical causes, involved in and controlled by the hereditary constitution of the mother-cell, and that any modification of this hereditary constitution must give rise to a corresponding modification in the results. Further than this I fear we cannot at present venture.

It has frequently been objected to the theory of natural selection that, however much useful characters may be encouraged and fostered in the struggle for existence, it cannot account for the first appearance of such characters. This appears to me to be a very fair criticism. It seems to me, also, very misleading to speak of the *origin* of species by natural selection, for *specific* characters throughout the animal and vegetable kingdom are, I believe, generally non-adaptive, and therefore cannot be directly due to natural selection. This is certainly the

case with the specific characters of sponges, which, as we have seen, depend for the most part upon trivial microscopical differences in the shape of the spicules.

Without entering upon the vexed question of the relation between somatogenic and blastogenic characters, we may assume in our ignorance that such characters as those which we have been discussing arise fortuitously in the germ-plasm, and that it is a mere chance whether or not they may prove to be of any value to the organism. If they are valuable, natural selection will foster and encourage them; if they are not, they may nevertheless persist for many generations unless too injurious to their possessors. If linked by correlation with useful characters they may be indirectly fostered by natural selection, and undergo a course of evolution parallel to that of their correlative characters. Although they may be useless at first, they may acquire some special value under new conditions of life, or in the course of their evolution under the old conditions, and then natural selection will begin to act upon them directly.*

Possibly all the characters which an organism exhibits, with the important exception of those which are due to the effects of use and disuse of organs, or to the response of the organism in some other way to the direct action of the environment, have first arisen as by-products of the complex chemical and physical processes upon which the life of the organism depends.

There is one more aspect of the problem to which I should like

* Having been asked to give a definite example of a character which, at first useless, has ultimately acquired an adaptive value, I suggest the pattern of the venation on the front wings, or tegmina, and on the leaf-like outgrowths of the abdomen in the leaf-insect *Pulchriphyllium crurifolium*. This venation so closely resembles that of a leaf as greatly to increase the remarkable protective resemblance which undoubtedly enables the insect to conceal itself effectively from its enemies. The mere *pattern* of the venation in the more primitive and typical Orthoptera can hardly have had any selective value. Of course the venation itself must always have been useful, both for supporting the wings and for supplying them with air, etc.; but as regards the pattern which the venation makes (which is the character to which I refer) one type of arrangement would seem to have been as good as another until it acquired a special adaptive value as a factor in bringing about protective resemblance to a leaf, and then doubtless the pattern evolved under the influence of natural selection until it reached its present degree of perfection.

to direct your attention before concluding. The constancy in the specific form of the microscleres of the Tetraxonida appears to be much greater in the case of the sigmatose than in that of the astrose series, and in the former at any rate seems to point to the different modifications having arisen as mutations rather than as fluctuating variations. This would, I think, be quite in harmony with the views which I have been endeavouring to express. A mutation, however small it may be, is believed to be due to some change, apparently sudden, in the constitution of the germ-plasm, which may then remain without further alteration until another mutation occurs. To say that the change in question is probably of a physico-chemical character seems almost a truism; but if it is so it seems only natural to suppose that such a modification, transmitted by cell-division to all the mother-cells of a particular kind, may affect in a uniform manner the form of all the microscleres deposited in these mother-cells, just as a change in the character of the reagents employed will affect the form of osmotic growths experimentally produced. If this view be correct, we must suppose also that any adaptive modifications with which the modifications of the microscleres may possibly be correlated must also have arisen as mutations. I see no objection to such a supposition, for mutations, if they occur sufficiently frequently, may be quite as valuable from the point of view of natural selection as small fluctuating variations.

We do not, of course, know what may be the cause of the modification in the constitution of the germ-plasm that gives rise to a mutation, but there is some reason to believe that it may be due either to the permutations and combinations of ancestral characters which take place in the maturation and fertilisation of the germ-cells, or to the influence of some change of environment upon the germ-plasm. If the characters of sponge spicules are really of the nature of mutations it should be possible to obtain Mendelian results by hybridisation, and I hope that at some time in the future experiments may be made with this object in view. The difficulties in the way of carrying out such experiments would probably, however, be very great, and we should require to know a great deal more than we do about the breeding habits and life-history of sponges before we could hope to bring them to a successful issue.

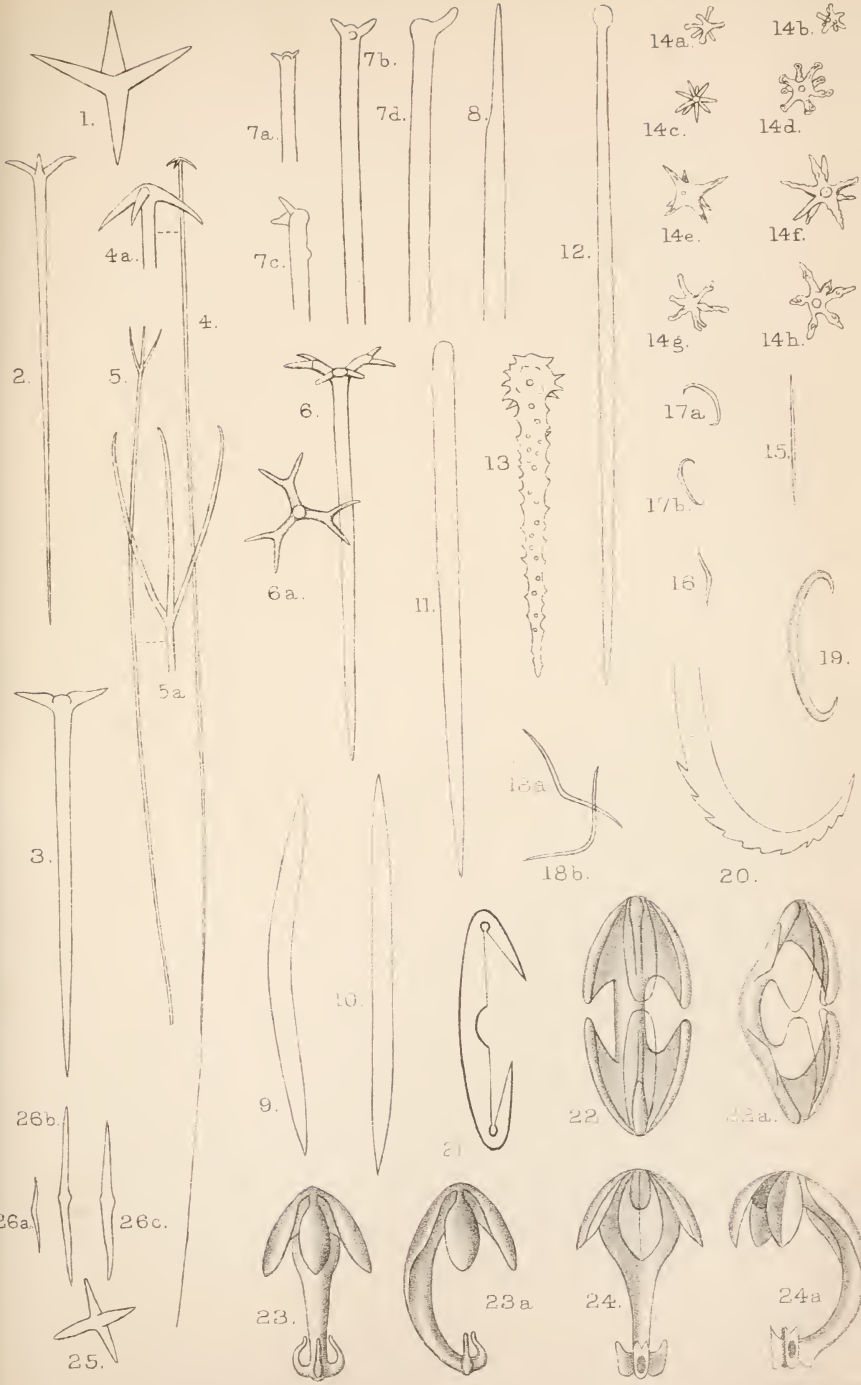
Description of Plate 7.

Fig. 1. Ideal primitive tetraxon.
„ 2. Plagiotriaene of *Ecionema carteri*, × 52.
„ 3. Orthotriaene of *Pilochrota hornelli*, × 52.
„ 4. Anatriaene of *Tetilla poculifera*, × 52.
„ 4*a*. Cladome of 4 × 230.
„ 5. Protriaene of *Tetilla poculifera*, × 52.
„ 5*a*. Cladome of 5 × 230.
„ 6. Dichotriaene of *Ecionema laviniensis*, × 52.
„ 6*a*. Cladome of 6, seen from above, × 52.
„ 7*a*–7*d*. Ends of triaenes of *Stelletta vestigium*, with reduced cladi, × 230.
„ 8. End of oxeote of *Stelletta vestigium*, × 230.
„ 9. Angulated oxeote of *Pachychalina subcylindrica*, × 360.
„ 10. Straight oxeote of *Reniera pigmentifera*, × 360.
„ 11. Style of *Axinella halichondrioides*, × 230.
„ 12. Tylostyle of *Hymedesmia curvistellifera*, × 230.
„ 13. Spined tylostyle of *Myxilla tenuissima*, × 530.
„ 14*a*–14*h*. Astrose microscleres of *Xenospongia patelliformis*, × 530.
„ 15. Microxeote microsclere of *Desmacella tubulata*, × 230.
„ 16. Toxiform microsclere of *Gellius angulatus* var. *canaliculata*, × 230.
„ 17*a*, 17*b*. Sigmata of *Gellius angulatus* var. *canaliculata*, × 230. (Note the angulation of the spicule, suggesting derivation from a diactinal microxeote, such as is represented in figs. 26*a*–26*c*.)
„ 18*a*, 18*b*. Toxa of *Toxochalina robusta* var. *ridleyi*, × 230.
„ 19. Sigma of *Desmacidon reptans*, × 512.
„ 20. End of sigma of *Paresperella serratohamata*, × 530.
„ 21. Diancistron of Vomerula or Hamacantha, × about 200.
„ 22. Isochela of *Esperiopsis pulchella*, front view, × 284.
„ 22*a*. Side view of same, × 284.
„ 23. Anisochela of *Cladorhiza pentacrinus*, front view, × 700.
„ 23*a*. Side view of same, × 700.
„ 24. Anisochela of *Cladorhiza* (?) *tridentata*, front view, × 360.
„ 24*a*. Side view of same, × 360.

Fig. 25. Primitive tetraxon (calthrops) of *Dercitopsis ceylonica*, × 230.

„ 26*a*–26*c*. Small oxea of *Dercitopsis ceylonica*, × 230. (Oxea four or five times as large occur in the same sponge.)

(Figs. 2–18*b*, 20, 25–26*c*, from Dendy's Report on the Sponges collected by Prof. Herdman at Ceylon in 1902. Figs. 19, 21, 22, 22*a*, 24, 24*a*, from Ridley and Dendy's Report on the *Challenger* Monaxonida. Figs. 23, 23*a*, from Dendy in *Ann. & Mag. Nat. Hist.*, Ser. 5, vol. 20, Pl. xv.)



Spicules of Tetraxonid Sponges.

ON FIVE NEW SPECIES OF BDELLOID ROTIFERA.

By David Bryce.

(*Read March 25th*, 1913.)

Plates 8 & 9.

The five species of which descriptions are furnished in the present paper have been known as distinct forms for many years past, although their distinguishing characteristics have not hitherto been gathered into the formal diagnosis which constitutes scientific baptism. Four of them belong to that important section of the Philodinidae in which the food is formed into pellets after passing through the mastax, and are assigned to the genus Habrotrocha. The fifth species belongs to the more numerous section of the same family in which the food is not at any time agglutinated into pellets, and being oviparous and possessed of three toes is a member of the genus Callidina, as now restricted.

Under the name of *Habrotrocha munda*, I describe the form to which I referred in some remarks upon the identity of *Callidina elegans* Ehrbg., appended to my paper on "A New Classification of the Bdelloid Rotifera," * as having been wrongly identified as that species by Hudson and Gosse and by other writers. I have endeavoured in that place to show as clearly as possible my reasons for the belief that this form cannot be that which Ehrenberg described; and inasmuch as none of the various correspondents who have addressed me with regard to my classification have advanced a view contrary to my own in this matter, I think that this victim of mistaken identity may now be established on a firmer and less assailable basis.

This species is the most common of the few pellet-making forms which have their usual habitat in ponds and ditches. In fresh gatherings it may frequently be seen swimming vigorously with its head slightly deflexed, or perhaps marching about at a great

* *Journ. Q. M. C.*, Ser. 2, Vol. XI., p. 61.

pace, and will often attract attention from the bright reddish colour of the stomach wall. On closer examination it may be readily recognised from the peculiar shape and pose of the spurs, which are quite distinctive, and from the many-toothed rami. Under more natural conditions, it takes shelter in any convenient recess among debris or in leaf axils, and there makes its home, protruding the head and neck when it desires to feed.

The second species, *Habrotrocha torquata*, has similar many-toothed rami, but in several other respects differs distinctly from *H. munda*. I believe that in some quarters it has also been accepted as *Callidina elegans* Ehrbg., probably on account of the rami. Unlike *H. munda*, it is never found in ditches or ponds, but has its habitat usually in mosses growing in positions frequently wet. The spurs are of simple form and the stomach wall is never of reddish tint. It has not been observed to seclude itself in any way and is of comparatively quiet habit. Its specific name was suggested by a curious but illusory appearance in some positions of an annulus encircling the expanded corona.

The third of the pellet-making species, *Habrotrocha spicula*, is a rather smaller form, which has the, so far, unique distinction of a single spine of small size placed on the pre-anal segment on the median dorsal line. When the body is contracted, or when the animal is seen in lateral view, this spine is sufficiently obvious, but at other times it is most easily overlooked. In my own experience this Bdelloid has only occurred in hilly country in elevated positions, but I learn from Mr. James Murray that he has also met with it in lowland habitats.

The fourth species, *Habrotrocha ligula*, is one of those puzzling forms which can only be recognised with certainty when it is feeding. It is mainly distinguished by the possession of a small fleshy tooth, which stands erect in front of the narrow sulcus between the two pedicels of the corona, difficult to discern except in direct dorsal view. In other respects it offers little to remark.

For my earliest knowledge of the new Callidina, I am indebted to my esteemed correspondent the late Forstmeister L. Bilfinger,

of Stuttgart, who sent to me, as long ago as 1894, a sketch of the animal together with some moss in which it occurred. I have therefore given it the specific name *Bilfingeri*, in honour and in grateful appreciation of a most courteous correspondent and of a painstaking and careful observer of the Rotifera. The type form of this species is marked by a series of lateral and dorsal knob-like prominences on the posterior half of the trunk. As in most other species with such knobs or with spines, the presence of these ornaments is not constant, and occasional examples are found in which some or even all the typical prominences are absent.

Habrotrocha munda sp. nov. (Pl. 8, fig. 1).

Specific Characters.—Corona moderately wide, exceeding collar; pedicels with dorsal inclination; discs more strongly inclined in same direction. Under lip relatively high, centrally prominent and spoutlike. Dorsal antenna long. Rami with seven or more fine teeth. First foot joint with dorsal prominence. Spurs resembling caudal processes of Chaetonotus.

In general build and in the somewhat "smothered" appearance of the corona, due in this case to the shortness of the pedicels and to the very oblique setting upon them of the trochal discs, this species has a certain resemblance to *Habrotrocha torquata*, but can usually be distinguished from it by the shape of the spurs, which in typical specimens have a very characteristic moulding and pose. In the normal or extended position, the body is spindle-shaped, distinctly larger about or a little behind the centre, and smaller at either extremity, and rarely exceeds 320 μ in length. While the rostrum is shorter and thicker than usual, the head and neck are only moderately stout, the trunk being distinctly larger (sometimes almost swollen when well fed), the lumbar segments short and tapering rapidly to a relatively small and slender foot of (I think) three segments. When creeping, the dorsal and lateral longitudinal skin-folds are usually well marked. In adult examples the stomach wall is frequently of a vivid reddish colour, and the lumen of the stomach is usually crammed

with obvious food pellets. The first foot segment has a median dorsal prominence of moderate height, rather wider than long, and best seen in lateral view. The second segment has the very characteristic spurs, which always suggest to me the caudal processes of the common form of Chaetonotus. They are longer than is customary among pellet-making species, frequently measuring 14 to 15 μ in length, but are sometimes much shorter. Near the base they are swollen on the inner side, and closely approximate. About mid-length they suddenly diminish in thickness and are thence produced to rather acute points. The outer side of each is nearly straight, and they are held at a slightly divergent angle. The three toes are difficult to see, but the terminal pair (and I think the dorsal toe as well) are moderately long and acute. The dorsal antenna is sometimes quite 25 μ long and is carried much as in *Rotifer macroceros*, being inclined backwards when the animal is creeping about, and directed more or less forward when it is feeding.

The corona attains a width of about 45 μ. The trochal discs are separated by a shallow furrow, which narrows to a mere notch as it nears the ventral side. On that side accordingly the principal wreath is almost uninterrupted, and in place of the customary appearance in front view of two distinct "wheels" there is rather that of a toothed band passing rapidly round a single transversely elliptic course, distinctly broken on the dorsal side and only slightly indented on the ventral. In lateral view it is seen that the pedicels are dorsally inclined, short and obliquely truncate, so that the trochal discs are still more inclined towards the dorsal side. The under lip and mouth margins are high in relation to the discs, and the former centrally prominent and spout-like as in *Habrotrocha angusticollis*, but in a lesser degree. The upper lip is usually hidden by the reverted rostrum. So far as I have been able to discern, it rises moderately towards the centre and is neither bilobed nor reflexed. The rami are about 19 μ in length, somewhat triangular in outline, and have each at least seven very fine teeth.

Habrotrocha munda occurs most frequently in pools, especially when water-mosses and anacharis are present. I have also found it occasionally in sphagnum and in confervae, both in floating masses and in the growth upon submerged stones. In suitable situations it makes for itself a rough case or nest of the same type as that produced by *Rotifer macroceros*.

It is of cosmopolitan distribution. I have noted it for England, Scotland, Germany (Baden, Black Forest, Wurtemberg, Stuttgart), Cape Colony.

Habrotrocha torquata sp. nov. (Pl. 8, fig. 2).

Specific Characters.—Of medium size and stoutness. Corona equal to or rather exceeding collar; pedicels short, distinct; trochal discs more or less dorsally inclined. Upper lip moderately high, undivided but centrally slightly reflexed; under lip unusually high, yet scarcely prominent. Dorsal antenna rather long. Rami with six or more fine teeth. Spurs short, divergent, conical.

When creeping about, *H. torquata* is somewhat difficult to recognise, as it lacks any conspicuous peculiarities of form, colour or size. It is perhaps most usefully described by comparison with other species of the same genus having similar many-toothed rami. The body is of moderate dimensions, less spindle-shaped than in *H. munda*, but less parallel-sided than in *H. elegans* (Milne). The rather short foot is longer and more distinct than in the latter species, but is less so than in *H. constricta* (Duj.). The spurs are simple short cones of moderate stoutness, and are held at almost a right angle, differing thus from the slighter and widely divergent spurs of *H. constricta*, the short, peg-like, very slightly divergent spurs of *H. elegans* (Milne) and the comparatively long moulded spurs of *H. munda*. In most examples the stomach is not obviously tinted, but is occasionally of a yellowish colour, yet never of the reddish shade frequent in *H. munda*, *H. auriculata*, and other species.

In habit it resembles *H. constricta*; that is to say, it lives in the

open and is not a dweller in the shelter afforded by natural or contrived gatherings of dirt particles or debris like *H. elegans* (Milne) and *H. munda*. I have never met with it in pools, but usually in mosses (not sphagnum) growing in wet positions. When the corona is displayed, it is seen to have a quite unusual appearance. As in *H. munda*, the trochal discs are inclined towards the dorsal side, but in a varying degree, and are separated by a furrow deeper than in that species. The upper lip rises in a broad rounded lobe which is centrally bent back, leaving visible the fleshy connection, or nexus, between the short pedicels. On the ventral side the under lip rises unusually high, and thus in dorsal view, the collar, which passes round the pedicels on either side and merges gradually into the under lip, has an obliquely upward direction, not obliquely downward as customary. This results in the optical presentments of the rapidly beating cilia of the secondary wreath (those lining the collar and passing round to the mouth), and of the cilia of the principal wreath (those of the trochal discs), being to some extent commingled, and there is the appearance of an annulus or ring passing round the trochal discs immediately below their margins. When the discs are seen so that their planes are nearly coincident with the line of sight, they appear to have deeply grooved margins, but the exact appearance varies with the angle at which they are viewed. Whether the appearance be that of a ring or of discs with deeply grooved margins, it is in my opinion purely an optical effect arising from the mutual interference of the light rays from the two wreaths of cilia.

The high under lip is unusually flat and inconspicuous; the lateral margins of the mouth are scarcely thickened and the mouth cavity is small as compared with that of other Philodinidae. When feeding the lumbar plicae are well marked.

The foot represents about one-ninth of the total length. It has four joints, the first having dorsally a distinct thickening of the hypodermis.

In the confinement of a small cell *H. torquata* proved only

moderately hardy. After a few days, most specimens would feed freely under the unaccustomed light and would remain quiet, but I have never known eggs to be laid under such conditions.

By no means a common species, yet widely distributed; I noted it first in moss sent me in 1895 by Forstmeister L. Bilfinger, of Stuttgart. I have since found it in moss from Epping Forest, Essex; Chagford, Devon; Pass of Leny, Perthshire; Black Forest, Baden.

Dimensions.—Greatest length 410 μ, more frequently 320 to 350 μ. Corona 38 to 41 μ. Rami about 15 μ. Spurs 6 to 9 μ.

Habrotrocha spicula sp. nov. (Pl. 9, fig. 1).

Specific Characters.—A single, short, blunt spine, sub-erect upon dorsal median line of pre-anal segment. Corona small, 13–18 μ wide; pedicels adnate; upper lip high, rounded, undivided. Rami with four teeth each. Spurs, short cones, widely separated.

A rather small species, chiefly noteworthy for the solitary spine and its unusual position. No other Bdelloid yet known has only a single spine or has spines only upon the pre-anal segment as in this case. When the animal is in its most retracted position, as one usually sees it lying inert among moss debris, the spine stands out distinctly at the hinder end of the body, and it is also well shown when the animal is feeding and assumes the squatting position natural to many species. It is easily overlooked when the animal is crawling about unless a good side-view is presented. It springs from a thickened base, and is rather blunt, short and slightly bent.

When seen from the front the very small corona is nearly circular in outline, the trochal discs being separated by a shallow furrow and the pedicels adnate. In dorsal view the high rounded upper lip rises quite to the level of the trochal discs, and its apex indeed is visible in ventral view. The margins of the mouth have small angular lateral prominences, which are partly

visible even from the dorsal side and add to the apparent width of the collar.

When extended the body is moderately stout and the longitudinal skin-folds are well marked. In most cases it is colourless, but examples of a faintly reddish colour have been seen. The antenna is short, but rather stout. The rami are small, 14–15 μ long.

The foot tapers rapidly and is very short. In the feeding position it is usually hidden beneath the trunk. It seems unsuited for crawling on a smooth surface such as glass, as the animals have unusual difficulty in getting foothold. The first joint has frequently a strong protuberance on its dorsal side. The spurs are very small cones about 3 μ long separated by an interspace about 6 μ wide.

The largest examples measured were about 200 μ long when extended, but others were from 170 to 185 μ. My earliest specimens were found in mosses collected for me on Cader Idris by Mr. D. J. Scourfield in 1895. Others came from collections on Mickle Fell and on Snowdon by the same friend. In 1898 I found it in moss from the top of Ben Ledi, in 1907 from the top of Ben Vrackie, both in Perthshire; and in 1906 from tree-moss in the woods above Triberg in the Black Forest, Baden. It has also been found repeatedly by Mr. James Murray in Scotland and in many foreign habitats.

Distribution: cosmopolitan, mostly at high elevations.

Habitat: ground, rock or tree-mosses.

Habrotrocha ligula sp. nov. (Pl. 9, fig. 2).

Specific Characters.—Moderately slender. Corona somewhat wider than collar; pedicels rather high, semi-adnate; discs separated by narrow sulcus. Upper lip rising very slightly and displaying a small fleshy tooth, which near its apex tapers suddenly to a point. Rami with four teeth each. Foot three-jointed; spurs small, tapering cones with interspace nearly equal to their length.

A species of rather less than medium size which in its extended position offers no obvious character for its recognition. The rostrum is short and stout, and the dorsal surface has a distinct almost ridge-like thickening of the hypodermis, best seen in lateral view. Its movements are active when crawling about, and when feeding it sways and bends almost incessantly in all directions, the body being well extended and the upper foot joints visible. The trochal discs are rather small and the greatest width of the corona little exceeds that of the collar. The pedicels are adnate to nearly half their height and are very slightly divergent. At the dorsal end of the nexus between them is a small fleshy ligule or tooth, which for the most part is nearly cylindrical, but near the tip tapers rather suddenly to a point. It is so inconspicuous that it can rarely be seen except in direct dorsal view and when the animal keeps steady for a brief interval. Even then the exact shape of the ligule is difficult to determine, but I think that it differs somewhat from the type of ligule possessed by any of the few Bdelloids in which this peculiar ornament or organ has been seen. In *Habrotrocha eremita* (Bryce), in which it was first noted, it is a simple, short, peg-like tooth, very slender and tapering gradually, and, to judge from the figures given by Murray, it appears to be of the same character in *Habrotrocha acornis* Murray and *Callidina lepida* Murray. In the present species the appearance is rather that of a fleshy cylindrical pedestal, with a tapering point inset at the end of the pedestal as if in a socket.

The upper lip rises in a low curve about as high as the base of the ligule. The rami have four teeth, but one tooth on each is much less prominent than the others. I have noticed that the food pellets are rather small. Examples isolated produced eggs of oval outline, hyaline, smooth-shelled, measuring 70 μ at the longest by 43 μ at the shortest diameter.

I had this species first in 1894 from a roadside near Deal, and in the following year from a wall in Bognor; in both cases from small button-like tufts of wall-moss. I did not see it again until

some few weeks ago, when it was brought to me by Mr. G. K. Dunstall, who had obtained it from moss collected near Leith Hill, in Surrey. It is probably a more common species than these three isolated records would indicate. It may be that it has a partiality for small tufts of moss (which do not invite examination), or perhaps its restlessness and the absence of any very obvious peculiarity when marching about has led to its being overlooked.

In view of Murray's opinion that the presence of a ligule in Bdelloids is an unsafe specific character, as it often appears in species where it is not normally present, it must be pointed out that, while it may be presumed that the ligule in *Habrotrocha ligula* is fairly constant, it is by no means impossible that examples should occur in which it might be absent, and in that case, if normal specimens were not available for comparison, identification might well be difficult.

Dimensions.—Length about 320 μ. Corona 30 μ. Collar 25 μ. Ramus 17 μ. Spurs 5 μ.

Callidina Bilfingeri sp. nov. (Pl. 9, fig. 3).

Specific Characters.—Of medium size, and moderately stout, posterior trunk having a series of knob-like prominences. Trochal discs well separated, but corona not exceeding collar width. Upper lip rather high and wide, with shallow central depression. Rami with two teeth each. Dorsal antenna short, about half the neck thickness. Foot three-jointed; first joint laterally swollen, second very short, somewhat distended to form sucker-like disc. Spurs very minute cones, with wide, slightly convex interspace.

So far as I am aware, this rather well-marked species, of moderately stout build and medium size, has been met with only in ground-mosses. Typical specimens are easily recognised from the series of knob-like prominences which ornament the sides of the trunk segments and the dorsal surface of the rump segments.

The number of these "knobs" appears to be very inconstant, as in sketches made by Forstmeister Bilfinger, James Murray, and myself it varies from eleven to five; and I was informed by the first-named correspondent that he had met with examples without any knobs at all. In such cases the species can still be determined with moderate certainty from the peculiar structure of the second foot joint, and the minuteness and wide separation of the spurs. When the full number of prominences are present they are distributed thus: the third segment of the trunk (or central portion of the body) has one at either side, close to its anterior boundary; the same segment and the fourth and the sixth have each one at either side near their posterior boundaries; while on the dorsal side of the fifth and sixth segments there are three more, arranged in a triangle (two in front on the fifth and one behind on the sixth segment, the latter on the median line). The fifth segment is moderately swollen laterally. The lateral knobs on the sixth segment (the anal) are more nearly constant than the others. Those most frequently absent are the anterior pair of the third segment.

The first foot joint has distinct lateral swellings, and is perhaps swollen dorsally as well. The second joint is very short, and slightly distended with thickened skin, forming a sucker-like disc from the lower surface of which the three short, broad toes are protrusible. The flange-like hinder margin of this foot disc forms the slightly convex interspace between two very minute spurs.

When creeping about the animal is seen to have a short and stout rostrum. In the feeding position the body is somewhat flattened, and the dorsal longitudinal skin-folds are obliterated. The trochal discs are well separated, but the head is stout and the corona does not exceed the collar width. The upper lip rises rather widely and high, and has a shallow central depression. The rami are 14 to 16 μ long, and are widest above the middle. The anterior outer margin of each is distinctly thickened, and passes gradually into a delicate winglike expansion of the ramus.

As already stated, this species was first discovered by the late Forstmeister L. Bilfinger in the vicinity of Stuttgart, and notified to me in 1894. It was afterwards found by Mr. George Western, probably near London, and in 1904 by James Murray, near Fort Augustus. In 1906 I met with it in moss gathered on the bank of a roadside ditch near Triberg, in the Black Forest. Quite recently numerous examples have been found in moss collected by Mr. G. K. Dunstall near Leith Hill, Surrey.

Dimensions.—Length about 315 μ. Corona 38 μ. Collar 41 μ. Spurs 1 to 2 μ (on inner edge).

Description of Plates 8 and 9.

Plate 8.

Fig. 1. *Habrotrocha munda* sp. nov., extended, dorsal view, $\times 350$; 1*a*, head and neck, corona displayed, in lateral view, $\times 650$; 1*b*, the same, in ventral view, $\times 750$; 1*c*, mouth, in front view (diagrammatic).

,, 2. *Habrotrocha torquata* sp. nov. In feeding position, corona displayed, dorsal view, $\times 550$; 2*a*, spurs, $\times 1600$.

Plate 9.

Fig. 1. *Habrotrocha spicula* sp. nov. In feeding position, corona displayed, ventral view, $\times 600$; 1*a*, retracted position, $\times 600$; 1*b*, foot extended, dorsal view, $\times 800$; 1*c*, ramus, $\times 1600$.

,, 2. *Habrotrocha ligula* sp. nov. In feeding position, corona displayed, dorsal view, $\times 480$.

,, 3. *Callidina Bilfingeri* sp. nov. In feeding position, dorsal view, $\times 350$; 3*a*, ramus, $\times 1600$.

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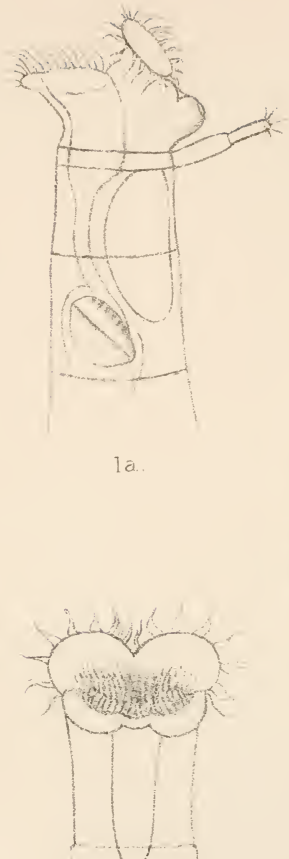

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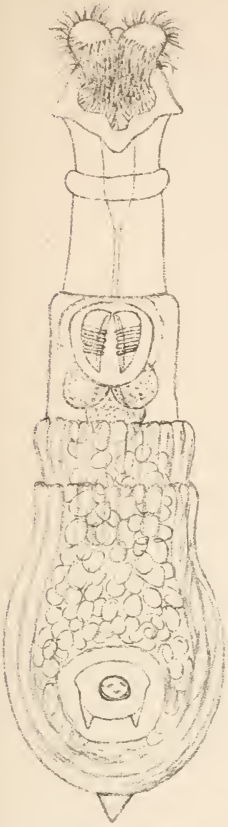
D. Bryce del. ad nat.

A. H. Searle, lith.

New Species of Bdelloid Rotifera.



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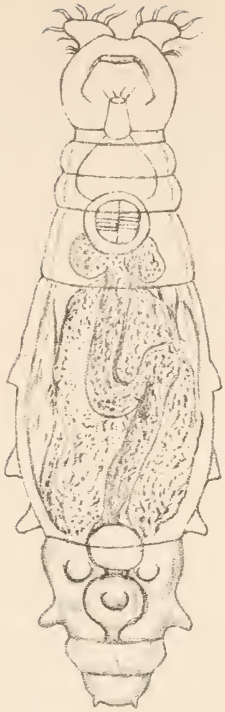

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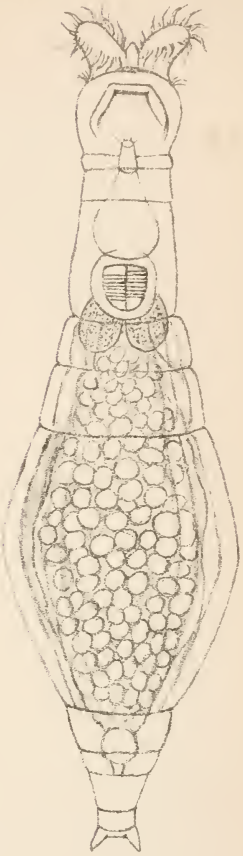

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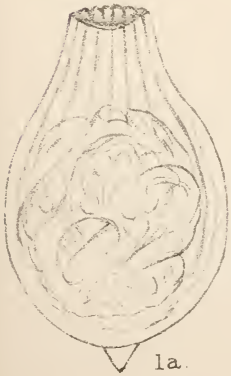

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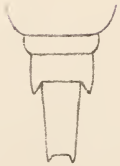

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3a.

D. Bryce del. ad nat.

A. H. Searle. lith

New Species of Bdelloid Rotifera.

NOTES.

A NEW LOW-POWER CONDENSER

By Edward M. Nelson, F.R.M.S.

(*Read November 26th*, 1912.)

The condensers which at present are supplied with microscopes are only suitable for low powers ranging from $\frac{2}{3}$ inch upwards. With powers lower than these a difficulty arises, for it is not possible to fill the field with the image of the source of light focused upon the object, as it should be. Substage condensers suitable for low powers are all too short in focus, consequently the image of the source of light is far too small.

In these circumstances microscopists have been, and are, accustomed to waive critical illumination and employ the most uncritical of all illumination, viz. to focus the image of the source of light upon the front lens of the objective; this is nothing more nor less than lantern illumination, which gives a critical image of a diaphragm limiting the field, but of nothing else; all delicate lines and structures are coated with black diffraction borders.

The obstacle in the way of using a long-focus condenser is that there is not sufficient room to focus it.

Powell's No. 1 stand has a good deal of room, but not enough, and other microscopes are simply nowhere. Now the way this difficulty may be surmounted is to construct the condenser upon the telephoto principle. This has now been done, and Messrs. Baker will show you this evening a substage condenser they have made from my design which has 4 inches of focal length and requires only 1 inch of working distance. With this condenser the image of the flat of the flame bears the same relation to a 4-inch objective with the large field of a P. & L. No. 1 A eyepiece, as the image with one of the ordinary universal condensers, with the top off, does to a $\frac{2}{3}$ inch; and this is precisely what was wanted.

Now let us understand exactly what this means. A 4-inch objective has a focal length of $2\frac{3}{4}$ inches; with a No. 1 A eyepiece the size of the object on the stage that is embraced

in a field of view is $\frac{6}{10}$ inch, therefore it is necessary for the condenser to focus upon the stage an image of the flat of the flame $\frac{6}{10}$ of an inch wide.

The condenser has a low aperture of N.A. 0·14, but large enough for the objectives for which it is intended to be used.

NAVICULA RHOMBOIDES AND ALLIED FORMS.*

(Addendum.)

By Edward M. Nelson, F.R.M.S.

(*Read November 26th*, 1912.)

With reference to the question, "What was the Amician Test?" quite accidentally I recently came across a notice to the effect that the test used by the Jurors at the International Exhibition (London, 1862) was the *Navicula rhomboides* under the name of *N. affinis*. This of course clears up all the difficulty. This *N. rhomboides* would have been of the kind termed the "English" *rhomboides* in my paper, and would have had 72 to 73 striae in 0·001 inch.

ON MICROSCOPE CONSTRUCTION AND THE SIDE SCREW FINE ADJUSTMENT.

By Edward M. Nelson, F.R.M.S.

(*Read November 26th*, 1912.)

There is one point which has been overlooked with respect to the evolution of the microscope. It is thought that the modern plan of placing the coarse adjustment slide and the body upon the fine adjustment was the invention of Zentmayer (1876), and that it first appeared in this country in the Ross-Zentmayer model. This however is not the case, for Powell in 1841 invented this plan, as well as that of the side pinion fine adjustment, now so much in vogue.

In the frontispiece of Cooper's *Microscopical Journal* an illustration of this model will be found.† Some years ago Mr. T.

* *Journal Q.M.C.*, Ser. 2. vol. ii. p. 93.

† This was the first microscope Powell introduced after Lealand had joined the firm (*vide Journal R.M.S.*, 1900, p. 287, fig. 78).

Powell kindly showed me one of these microscopes, but it had escaped my memory. The coarse adjustment was by rack and pinion; this was not attached to the limb by a slide, but by a kind of cradle. This cradle was pressed down by a spring on to a horizontal cone, which was moved by a horizontal fine-adjustment screw, which had a milled head on each side of the limb.

The importance of this model should be recognised by every one who uses a microscope, for not only was it the first microscope to have a side screw, but also it was the first instrument in which we find the limb attached to the foot on two upright pillars. This double support to the joint (now almost universally used) was the invention of George Jackson (President R.M.S. 1852-3). Before this all microscopes that were capable of being inclined were attached to the foot by a single upright post and a compass joint.* Powell attached the two pillars to a flat tripod base by a swivel so that the base could be placed in such a position as to give the greatest amount of stability however much the body might be inclined (some makers in copying this arrangement graduated this arc of rotation !).

Ross copied this kind of joint in the model he brought out in 1843, but substituted two parallel flat plates for the two pillars; but Messrs. Smith and Beck adopted the two-pillar form in their 1846 model.

This microscope of Powell's had a Turrell stage, a micrometer stage, an achromatic condenser, Nicol polarising and analysing prisms; so it was in its day an instrument of a very advanced type. In 1843 Powell & Lealand discarded the two pillars for the gipsy tripod, which is the best form of foot ever designed.†

Coming now to modern times, horizontal fine adjustments may be placed in two groups, viz. (*a*) those with continuous motion and (*b*) those without. The drawback which those of the first kind possess is that the user does not know whether he is focusing up or down; and the drawback which all the second kind, excepting the Berger, have is that of damage and injury to the delicate moving parts when they butt up against a stop. The Berger avoids all risk of damage from this source by causing

* Some ancient non-achromatic microscopes had ball and socket joints, but those early forms are not now under discussion.

† For fig. see *Journal R.M.S.*, 1900, p. 289, fig. 79.

an idle nut to butt against a stop; if this nut receives damage or strain to its thread it is of no importance. The first kind adopt a continuous motion in order to secure immunity from this danger, and put up with the great disadvantage of having a fine adjustment which does not follow the direction of the movement of the milled head.

The following simple device has been designed to effectually prevent any damage taking place. To the right hand side of the limb, where the micrometer drum-head is placed, a short piece of tube, threaded on the outside, is fixed, and through it the fine adjustment pinion passes just like the cannon pinion in a clock.

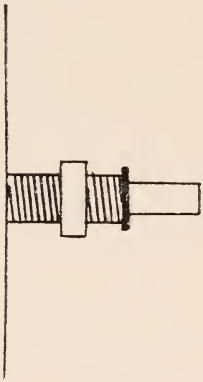

Fig. 1.

Fig. 2.

An idle nut works on this screw in a slot inside the micrometer drum. It is then arranged that this nut will permit ten rotations of the fine-adjustment pinion to be made, and then stop further motion by butting either against the side of the limb or against the end of the inside of the micrometer drum. Figs. 1 and 2 will make this simple device clear without further explanation.

NOTE ON *PLEUROSIGMA ANGULATUM*.

By Edward M. Nelson, F.R.M.S.

(*Read January 28th*, 1913.)

About the end of the eighties I took a photomicrograph of a specimen of *Pleurosigma angulatum*, which had been broken in a very remarkable manner so that it was possible to demon-

strate the existence of two membranes. At one part the upper membrane had been torn away leaving the lower membrane, at another the lower membrane had gone while the upper was left, the rest of the valve having both membranes in position. These three photomicrographs of the upper, lower and both membranes were exhibited to the Club. No other specimen I have seen has been so fortunately fractured as to demonstrate both membranes so clearly as this one.

The network in one membrane differs slightly from that of the other, so that after a little practice one is able to state whether the membrane under observation is an upper or lower membrane. The upper membrane in *P. strigosum* resembles the diamond panes of a leaded light, while the lower is like wire netting, fig. 3. In *P. balticum* and allied forms the upper membrane has slit-like apertures in longitudinal rows, while

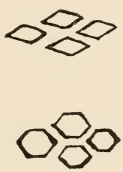

Fig. 3.

Fig. 4.

the lower membrane has circular apertures, fig. 4, where the circular apertures in the lower membrane are seen through the intercostal silex of the upper membrane and in a line with the bars between the slits.

Now at that time it was thought, and probably it is still the received opinion, that the lower membrane "eye-spotted" the upper membrane; by which is meant that the apertures in the lower membrane are directly below those in the upper membrane—much in the same way as in Coscinodiscus the eye-spot is directly below the perforated cap at the top of the cell.

Recently, however, study on *P. angulatum* with a Leitz apochromat, $\frac{1}{12}$ inch of 1·40 N.A., has caused me to change my opinion, for the apertures in the lower membrane can be unmistakably seen below the intercostals of the upper membrane, and this is true not only of *P. angulatum*, but also of all allied forms that have been examined.

No mention has been made of Mr. T. F. Smith's observation

on the structure of the genus Pleurosigma, because this note, not being an exposition of the structure of this genus, deals merely with the single fact of my altered opinion with regard to the apertures in the lower membrane not "eye-spotting" those in the upper.

The genus Pleurosigma has been seventy years before the microscopical world, not laid aside, but worked at continuously by the most skilful microscopists, yet all the problems connected with their structure have not been solved. It is only by recording from time to time a little bit here and a little bit there, and by putting these little bits together, that complete and accurate knowledge of this difficult subject will be attained.

ACTINOCYCLUS RALFSII AND A COLOURED COMA.

By E. M. Nelson, F.R.M.S.

(*Read January 28th*, 1913.)

The following account of a microscopical phenomenon, never previously observed, may be of interest.

When working on a mixed diatom gathering, dry and *uncovered*, with a Powell & Lealand $\frac{1}{4}$ inch and a lieberkuhn, there appeared round an *Actinocyclus Ralfsii* a wide border of brilliant orange, green and blue light. The inside of the valve was uppermost and the bottom of the cup was in focus, so that the surrounding mist was caused by the out-of-focus edge, which, of course, was at a higher level. Any one seeing this coloured mist would have exclaimed what a badly corrected objective! but if they had looked at the other diatoms in the field, they would have seen that the out-of-focus coma was white! The colour, then, must be a function of the Actinocyclus. Another objective with a lieberkuhn, viz. a Powell & Lealand $\frac{4}{10}$ inch, was tried on the same diatom; the border was now red, the green and blue having gone! A third objective, viz. a Wenham $\frac{1}{2}$ inch with lieberkuhn (really a $\frac{4}{10}$ inch), and the image seen had no colour!

Here, then, we have an example of an object affecting different objectives differently. Would some of our "brass and glass" experts kindly take this matter up?

NOTICES OF BOOKS.

PROBLEMS OF LIFE AND REPRODUCTION. By Marcus Hartog, M.A., D.Sc., F.L.S. 8 × 5¾ in.; xx + 362 pages; one plate, 41 figures in the text, and three diagrams. London: John Murray, 1912. Price 7*s.* 6*d.* net.

In taking up this book one cannot avoid a feeling of regret that the author was unable to carry out his original intention of writing a general treatise on Reproduction suited to the layman interested in biological questions. By his researches the author would have been well fitted for such a task. As it is, the book consists of a series of papers on debatable subjects in Biology gathered from various scientific journals and reviews, and ranging in date from 1892 to 1910. They have been revised in part in the light of more recent research, and brought up to date.

There is much to interest the microscopist, and to one who is not already acquainted with them in their original form they may be recommended. The earlier papers deal with the problems of reproduction as presented in the Protista—conjugation and rejuvenescence and the beginnings of sexual reproduction or syngamy. The paper on Fertilisation contains a large number of interesting facts gathered together; here the author puts forward the idea that it is the *linin* and not the *chromatin* (which only serves a purely mechanical function) which is the real transmitter of inherited properties. This idea is more fully developed in Chapter IV. on "Mitokinetism"—a new force which the author brings to our aid in explaining the mechanics of the mitotic process of nuclear division. Other chapters deal with heredity and the inheritance of acquired characters and Mechanism and Life.

There are a number of illustrations and a coloured plate; a full index is provided.

THE BEGINNER'S GUIDE TO THE MICROSCOPE, with a section on mounting slides. By Charles E. Heath, F.R.M.S. $7\frac{1}{4} \times 5$ in. 119 pages, 45 figures in text. London: Percival Marshall & Co., 1912. Price 1*s.* net.

In this elementary guide to the study of Microscopy the author has treated the subject from a practical point of view, leaving theoretical matters to the larger books on the subject. With this little book at hand the beginner cannot fail to gain a useful knowledge of the instrument, its care and its application. The methods of illumination, including the dark-ground method, are fully dealt with. As the author says, the book is intended "to enable an ordinary man in an ordinary way to interest himself and his friends by giving sufficient instruction to make him capable of seeing and showing some of the hidden wonders" revealed by the microscope.

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PROCEEDINGS

OF THE

QUEKETT MICROSCOPICAL CLUB.

At the meeting of the Club held on October 22nd, 1912, the President, Prof. A. Dendy, D.Sc., F.R.S., in the chair, the minutes of the meeting held on June 25th, 1912, were read and confirmed.

Messrs. William Elliott and Leabury Edwardes were balloted for and duly elected members of the Club.

Seventy-three members and five visitors were present. Thirteen proposals for membership were read by the Hon. Secretary.

The list of donations to the Club was read and the thanks of the members were voted to the donors.

A letter addressed to the President by Mr. Charles Peveril was read, intimating that the late Mr. J. M. Allen, F.R.M.S., had bequeathed to the Club his microscopes and apparatus belonging thereto. This legacy was accepted by the Committee; it consists of two microscopes and some small accessories.

The Librarian announced that he had received a copy of L. L. Clark's "Objects for the Microscope" to replace a copy missing from the library, also that Prof. Minchin's "Introduction to the Study of the Protozoa" had been presented by the author.

A communication from Mr. J. Rheinberg, F.R.M.S., "On Resolutions Obtained with Dark-ground Illumination and their Relation to the Abbe Theory," in the absence of the author, was taken as read.

A very interesting paper, "The Foraminifera in their Rôle as World-Builders," by Messrs. Earland and Heron-Allen, was read by Mr. Earland, and illustrated by a large number of pictures of the various forms described, which were shown upon

a screen by Mr. Ogilvy by means of the Epidiascope, and by specimens of the deposits placed upon the table.

The President said it was hardly necessary to ask them to give a hearty vote of thanks to Mr. Earland for reading them such an interesting paper. A vote of thanks was carried by acclamation.

Through the kindness of Messrs. Leitz's London representative, Mr. Ogilvy, the lecture was very efficiently illustrated by the use of the Leitz universal projection apparatus, which projected on the screen ordinary lantern-slides, plates and illustrations from books, etc., single photographs, microscopic sections at varying magnifications, rock hand-specimens and fossils. The capabilities of the apparatus, which employs an automatic L-arc, taking 30 amp. at about 60 volts, were further demonstrated by Mr. Ogilvy and his assistants after the meeting. The approximate candle-power produced is about 10,000. Micro-projection may be accomplished in the usual horizontal position, and, for hanging drop slides or other living preparations, a vertical position is also possible. Besides the projection of lantern-slides of any size up to 12 cm. square ($4\frac{3}{4}$ in.), for which a novel and exceedingly efficient holder is provided, it is also possible to project larger transparencies up to 20 cm. square (8 in.), or such preparations as brain sections, etc.

The President said they were all very much indebted to Mr. Ogilvy for what he had shown them; he had himself been greatly interested to see how perfectly the Epidiascope was adapted for showing drawings, lantern-slides and microscopic specimens on the screen in a manner which he had not previously been aware of.

The Hon. Secretary regretted to have to announce the recent death of Dr. M. C. Cooke, M.A., LL.D., A.L.S., one of the original founders of the Club, and President 1882–3.

At the meeting of the Club held on November 26th, 1912, the President, Prof. A. Dendy, D.Sc., F.R.S., in the chair, the minutes of the meeting held on October 22nd were read and confirmed.

Messrs. E. Pitt, G. C. Bellamy, T. Tonkin, H. Pulford, E. H. Bassett, L. C. Hayward, William Hill, D. A. Mardon,

P. E. Dollin, F. Whitteron, J. M. Coon, R. W. H. Row and W. Hardman were balloted for and duly elected members of the Club.

The list of donations to the Club was read, and the thanks of the members were voted to the donors.

The President said that members would be very glad to hear that the announcement made at their last meeting, of Dr. Cooke's death, was incorrect. They had it apparently on the best authority, and the scientific Press generally had been similarly misinformed. He was sure that all members would hope that Dr. Cooke would long remain a member of the Club.

The President asked members to extend a hearty welcome to a visitor, Dr. E. F. Hodges. Dr. Hodges was State Medical Supervisor for Indiana, U.S.A., had been for many years a Fellow of the Royal Microscopical Society, and took the greatest interest in microscopy generally.

Mr. C. Lees Curties, for Messrs. Baker, exhibited a new one-sixteenth oil-immersion objective of N.A. 1·32. It was made of a stable glass—one that would stand any climate. Its qualities were appreciated by members, who admired the excellent definition it gave (with a × 7 ocular) on a fine preparation of *Trypanosoma gambiense*.

The President made some remarks relating to a new species of Holothurian. He said he had no formal paper to read, but the subject had been before the Club a few months ago (*Journ. Q.M.C.*, Ser. 2, Vol. XI. p. 536), when an Australian visitor, Mr. F. Whitteron, of Geelong, had brought for distribution a number of specimens of a species of Holothurian which had an interesting history. They had been collected in Corio Bay, Port Phillip. Continental experts had identified the species as *Trochodota dunedinensis* (Parker). That identification, however, proved to be incorrect, and, as specimens had been distributed at their June meeting, he thought it proper to bring the matter before the notice of the Club. On examining the material he had then taken, he found that all the calcareous wheels had been dissolved, possibly by the medium in which they were preserved being, or becoming, slightly acid. Fortunately, this failure was not of importance, as, in a reprint he had received from the Proceedings of the Royal Society of Victoria, Mr. E. C. Joshua, of Melbourne, discussed the species found at Geelong, and

definitely showed that it was not identical with the New Zealand form. He calls the Geelong species *Taeniogyrus Allani*. The President referred to the varying nomenclature of these species. He considered all the forms closely related, and preferred the generic name Chiridota, applied by Parker to the New Zealand form. The differences between the New Zealand and Geelong species were then considered. The structure of the wheel spicule had been worked out by Mr. Joshua, and was described in his paper. The President had worked out the N.Z. form some years ago, and described and sketched on the blackboard the various stages observed. The spicule has a broad margin, corresponding to the rim of the wheel. Then there are six spokes radiating from the centre, and in some species there is a small hole in the middle. Specimens of *C. dunedinensis* exhibit a uniform minute toothing all round the margin, which is inturned. The other side of the wheel has a different appearance. The six spokes show as before; but the toothed edge is not seen at the top focus. Further, fresh detail is exhibited in the form of a six-rayed cross, which stands above the level of the spokes. A diagram of a vertical section was given. The President said it was a very curious and wonderful structure, and the development was of extreme interest. Commencing with the six-rayed cross, a thickening appears at the end of each ray, and on one surface only. This was the earliest stage observed. As the thickenings grow, they exert pressure on each other, and presently each spoke bifurcates at the extremity. The bifurcated ends begin to grow outward, and presently meet, and, fusing, form the rim of the wheel. The rim turns in, and is denticulated all round the margin. The spicule is, of course, useful as a skeletal structure; but it is not at all apparent why such a remarkable and elaborate form should be required. The chief differences in *C. Allani*, as compared with *C. dunedinensis*, are: The margin, instead of rounding off, remains hexagonal. The face showing the six-rayed cross is much the same, excepting that it also is hexagonal; but the toothed rim is not uniform, but follows a curve with little bays opposite the angles of the hexagon, and the toothing is pronounced in parts, but is absent from the bays or notches. It is very difficult to account in any way for such minute differences as those noted. The new form, which he would prefer to call *Chiridota Allani*, was first found by Mr.

J. M. Allan, near Geelong, and subsequently by Mr. E. C. Joshua.

Replying to a question, the President said that formalin was very unsafe to use in such cases, as it frequently becomes acid after a short time.

Mr. J. Burton said he took some of the material brought by Mr. Whitteron, and, after some trouble, had found some wheels in the skin. They looked as though acid had been previously applied. The wheels showed a tendency to break down into anchors, reminding one of the well-known Synapta spicules. The anchor form, as the President had said, was an early stage in the development of the wheel. The wheels, under a binocular, proved to be basin-shaped. There was a second kind of spicule, something like a drawer-handle in shape, and a third shape, found only in the tentacles, where it was very numerous, constituting, perhaps, 50 per cent. of their bulk.

The thanks of the meeting were unanimously voted to the President for his communication.

Several notes from Mr. E. M. Nelson were read to the meeting by the Hon. Secretary, as under:

1. "On Microscopic Construction and the Side-Screw Fine Adjustment," in which he traced the history of this form from 1841 to the present time, with some suggestions of his own for further improvement.

2. On the Navicula used as a test by the Jurors of the 1862 Exhibition, which he thought was the "English" rhomboides under the name of *Navicula affinis*.

3. "On a New Low-power Condenser" for use with objectives as low as 4 in., the ordinary condenser not filling the field with light when low powers were used.

The way this difficulty may be surmounted is to construct the condenser upon the telephoto principle. This has now been done, and Messrs. Baker exhibited to the meeting a substage condenser, made from Mr. Nelson's design, which has 4 in. of focal length, and requires only 1 in. of working distance. With this condenser the image of the flat of the flame bears the same relation to a 4-in. objective with the large field of a P. and L. No. 1, A eyepiece, as the image with one of the ordinary universal condensers with the top off does to a two-thirds; and this is precisely what was wanted.

The thanks of the Club were voted to Mr. Nelson for his communications.

At the meeting of the Club held on January 28th the President, Prof. A. Dendy, D.Sc., F.R.S., in the chair, the minutes of the meeting held on November 26th, 1912, were read and confirmed.

Messrs. Hilary Mavor, Robert Spry, E. J. Sheppard, F.R.M.S., A. C. Coles, M.D., D.Sc., A. M. Allison and H. W. Freeland were balloted for and duly elected members of the Club.

The list of donations to the Club was read and the thanks of the members voted to the donors.

Mr. Watson Baker, for Messrs. Watson & Sons, Ltd., exhibited and described a new model microscope which had a specially long horizontal travel, $1\frac{3}{4}$ in., to the mechanical stage, both movements working on the same axis. The fine adjustment is a vertical lever actuated by the now customary side-screw, and permitting the worker to always know whether the body is ascending or descending. It has a specially long range of coarse adjustment. The most important novelty on the stand was a new objective changer, made on the principle of a 3-jaw chuck; less than a quarter-turn of a collar is all that is necessary to engage or release an objective, and it does not increase the tube length. An auxiliary stage was also shown. This, fitted to the usual stage, will give nearly four inches of horizontal travel, and should be found very useful in working with large preparations.

Mr. A. A. C. Eliot Merlin, F.R.M.S., sent a photomicrograph taken at × 320 of *Coscinodiscus heliozoides*, showing extended "pseudopodia," from a preparation by Mr. J. D. Siddall.

The fine radiating "pseudopodia" can be well seen when the print is examined in a good light with a Verant or other suitable hand magnifier. The photograph gives the impression that the radiating filaments are real appendages of the organism, and the general appearance of these reminds one strongly of the pseudopodia of *Discorbina globularis* as figured in Carpenter (1901 edition), page 798.

The photograph as a whole strikes one as more curious than beautiful. It will, however, be noticed with a lens that several of the radiating filaments are very fine and in exact focus.

The best focal plane for the "pseudopodia" does not coincide with that for the diatom itself, and this, together with the prolonged exposure necessary to bring out the faintly illuminated filaments, causes the valve to be much over-exposed, making the diatom appear as a mere blurred, globular white patch in the print.

The President gave a résumé of a communication of some length by Mr. W. M. Bale, F.R.M.S., of Victoria, Australia, entitled "Notes on Some of the Discoid Diatoms." This paper was a survey of some of the principal characters which have been utilised in the discrimination of species in three or four of the best-known genera of discoid diatoms. Some of the conclusions arrived at as to the inadequacy of many of these distinctions have been reached by previous observers, more especially in the genus Coscinodiscus; but it was thought that in such cases the special instances now brought forward might be serviceable in reinforcing those conclusions. In other cases, particularly in the genus Actinoptychus, the author's observations tended to prove that characters accepted as specific even by recent authors were demonstrably unreliable. The genera dealt with included Coscinodiscus, Actinocyclus, Asteromphalus and Actinoptychus.

The thanks of the meeting were unanimously voted to the President for communicating this important paper.

A paper on "British Freshwater Rhabdocoelida (Planarians), a Group of Turbellaria," by H. Whitehead, B.Sc., in the absence of the author was read by Mr. J. Wilson.

After some discussion, in which Messrs. Scourfield and Hammond took part, the President said that the Rhabdocoelids were very low down in the scale, some of them ranking among the lowest of multicellular organisms. Most of his own work in Australasia had been done on land forms, but there were, possibly, water forms as well. There were in Australia an enormous number of land Planarians which lived under stones, rocks, logs, etc., and only came out at night. Some were very large, reaching a length of one foot. They are locally incorrectly termed "land-leeches." Many are brightly coloured in stripes, spots, and patches of brilliant blue, red, yellow, orange, and sometimes iridescent. These colourations were very useful in assisting naturalists to identify species. He had described some forty new

species from Australia and New Zealand, and was very glad to see that the study of the group was being taken up in this country.

The Hon. Secretary read a "Note on *Pleurosigma angulatum*," by Mr. E. M. Nelson, F.R.M.S., also a note on a coloured coma observed in examining *A. Ralfsii*, by the same author.

Mr. C. F. Rousselet, F.R.M.S., read a paper on "The Rotifera of Devils Lake, and description of a new Brachionus."

At the meeting of the Club held on February 25th, the President, Prof. A. Dendy, D.Sc., F.R.S., in the chair, the minutes of the meeting held on January 28th were read and confirmed. There were present ninety-three members and fourteen visitors.

Messrs. H. T. Laurence, F. W. Mills, J. W. Durrad, W. Oatley, E. A. Anstey, C. D. Hutchin, A. Booker, F. W. Parrott, J. J. Armitage, N. Burns, J. Snell, A. C. Trotman, R. A. Taylor, J. Bancroft, J. E. Barnard, R. Hall, V. Tyas and Dr. J. C. Kaufmann were balloted for and duly elected members of the Club.

The list of donations to the Club was read and the thanks of the members voted to the donors.

The President having appointed Messrs. Fuller and Watson-Baker, jun., as Scrutineers, the ballot for Officers and Council was proceeded with.

The Hon. Secretary (Mr. W. B. Stokes) read the Committee's forty-seventh Annual Report. It was considered that the past year was one of marked progress. Forty new members had been elected; five members had died and fifteen had resigned during the past year. The total membership on December 31st, 1912, was 406.

The Hon. Treasurer (Mr. F. J. Perks) presented the Annual Statement of Accounts and the Balance-sheet for 1912, which had been duly audited and found correct.

The Report and Balance-sheet were received and adopted, on the motion of Mr. Morland, seconded by Mr. Gaff.

The President, having asked Prof. E. A. Minchin to take the chair, delivered his Annual Address, taking as his subject "By-products of Organic Evolution."

Prof. Minchin said he was sure all present would agree that

they had listened to a very fascinating address from one who was the foremost living authority in Europe on sponge spicules. The Club was very fortunate in having the subject dealt with by him. The objects were quite well known to all microscopists, and he believed he was right in saying that all the different forms of spicules described could be obtained from sponges found on our own coasts. He had great pleasure in moving a hearty vote of thanks to their President for his address, and in asking him to allow it to be published in the *Journal*.

The motion having been put to the meeting, was carried by acclamation.

The President, in acceding to this request, thanked the members for the way they had received the address, but said he had thought himself that Prof. Minchin was the greatest authority they had on these microscopic objects.

A vote of thanks to the Auditors and Scrutineers, having been moved by Mr. W. R. Traviss and seconded by Mr. A. M. Jones, was put to the meeting and carried unanimously.

Mr. Bremner then moved that their best thanks be given to the officers of the Club for their services during the year. They had given them a very valuable amount of time with a most excellent result. Mr. Stokes had referred to the work done by their Librarian, which must have occupied hundreds of hours, and as for Mr. Stokes himself his unfailing courtesy and his capacity for hard work were deserving of their highest appreciation.

Mr. A. D. Michael said he always felt very strongly that the great success which attended the scientific societies of London was mainly due to the work done by their officers. He had much pleasure in seconding the vote of thanks to those who had so ably conducted the business of the Club during the year.

Mr. W. B. Stokes said that as this was the last occasion on which he would be able to speak as an officer of the Club he would reply for his colleagues; he thanked the members for the vote they had just carried. He felt he was leaving the Secretaryship in better hands than his own; but was very glad that he was leaving it not when the Club was at the bottom of a curve of prosperity, but very nearly at the top. He thanked the officers for the ready assistance which they had always given him, and which had rendered his duty a pleasant one, and he

desired also to thank the members for the kind way in which they had supported him during his term of office as their Secretary.

The President announced the result of the ballot for Officers and Committee to be as follows :—

President	Prof. Arthur Dendy, D.Sc., F.R.S., F.L.S.
Vice-Presidents . .	C. F. Rousselet, F.R.M.S. E. J. Spitta, L.R.C.P., M.R.C.S., F.R.A.S. D. J. Scourfield, F.Z.S., F.R.M.S. Prof. E. A. Minchin, M.A., F.R.S.
Treasurer	Frederick J. Perks.
Secretary	James Burton.
Assistant Secretary .	J. H. Pledge, F.R.M.S.
Foreign Secretary .	C. F. Rousselet, F.R.M.S.
Reporter	R. T. Lewis, F.R.M.S.
Librarian	S. C. Akehurst.
Curator	C. J. Sidwell, F.R.M.S.
Editor	A. W. Sheppard, F.Z.S., F.R.M.S.
Vice four senior Members retired.	R. Paulson, F.R.M.S. J. Grundy. M. Blood, F.C.S., F.R.M.S. C. D. Soar, F.L.S., F.R.M.S.
Vice James Burton (apptd. Secretary.)	R. Inwards, F.R.A.S.

FORTY-SEVENTH ANNUAL REPORT.

Reviewing the work of the Club during the year 1912 shows that it has been a period in which its high value to the user of the microscope has been again demonstrated. Not only has the Club maintained the interest of its meetings, but it has exhibited a revival of interest in matters connected with the instrument itself. There has been a very good attendance at conversational meetings, and the favour shown to the excursions during a season having a record rainfall is well worthy of note. The number of new members added during the twelve months is forty, 50 per cent. advance on that of 1911, and this number would have been even greater if an ordinary meeting in December had been possible. The Club has lost five members by death, and resignations have accounted for fifteen; this leaves a net gain of twenty members. The total membership on December 31st was 406.

The following communications have been made during the year :—

Jan.	James Burton. Notes on Algae collected in 1911.
Feb.	Prof. E. A. Minchin, F.R.S. Some Speculations with regard to the Simplest Forms of Living Beings and the Origin of Life.
March.	H. Sidebottom. Lagenae of the South-west Pacific.
„	C. F. Rousselet, F.R.M.S. On New Species of Rotifera.
„	D. Bryce. On New Species of Callidina.
„	A. E. Conrady, F.R.A.S. On Resolving Powers obtainable with Dark-Ground Illumination.
„	A. A. C. Eliot Merlin, F.R.M.S. On the Capped Secondaries of *Navicula Smithii*.
April.	John Stevens, F.R.M.S. On *Notommata gigantea* (Glascott).
„	Duncan J. Reid. Illumination in Critical Work.
May.	E. M. Nelson, F.R.M.S. On the so-called Pseudopodia of certain Diatoms.

May. R. T. Lewis, F.R.M.S. Notes on Solpuga.
„ A. E. Conrady, F.R.A.S. Some Experiments on Alternative Microscopical Theories.
June. W. B. Stokes. Resolutions obtained with Dark-Ground Illumination and their Relation to the Spectrum Theory.
„ R. W. H. Row. On a Saw-fly.
Oct. Julius Rheinberg, F.R.M.S. On Resolutions obtained with Dark-Ground Illumination and their Relation to the Abbe Theory.
„ A. Earland, F.R.M.S., and E. Heron-Allen, F.L.S. Foraminifera as World Builders.
Nov. Prof. Arthur Dendy, F.R.S. On a New Species of Holothurian.
„ E. M. Nelson, F.R.M.S. On Microscope Construction.
„ „ „ „ On *Navicula rhomboides.*
„ „ „ „ On a New Low-Power Condenser.

The following exhibits were made:—

Jan. E. M. Nelson, F.R.M.S. Photomicrographs.
„ A. Earland, F.R.M.S. Photomicrographs of Recent Foraminifera.
„ W. Watson & Sons, Ltd. Microscope Tray.
„ Charles Baker. Nelson's Dark-Ground Illuminator.
March. T. W. Butcher, F.R.M.S. Photomicrographs of *Navicula Smithii.*
„ Charles Baker. Nelson's Oil Immersion Dark-Ground Illuminator.
„ Charles Baker. Nelson's Improved Chromatic Condenser.
„ Charles Baker. Nelson's Improved Rousselet Compressor.
April. C. D. Soar, F.R.M.S. Drawings of Water-Mites.
„ A. W. Stokes. Electric Lamps for the Microscope.
„ C. F. Rousselet, F.R.M.S. Diatoms with "Pseudopodia."
„ Charles Baker. A New $1\frac{1}{2}$-in. Objective of N.A. 0·18.
Oct. E. Leitz. The Epidiascope.

Nov. Charles Baker. A New 1/16th-inch Oil Immersion Objective.

,, Charles Baker. Nelson's New Low-Power Condenser.

Your Committee wish to thank the authors and exhibitors for these interesting communications and exhibits. It will be seen that there has been no falling-off in either the quality or quantity of papers submitted to the Club.

There were eleven excursions during the season, and all were well attended, except on one occasion when the weather was very bad; the record number of fifty-three members met to visit the Royal Botanic Gardens. The total attendances for all excursions was 235, which is also a record for any one year, and the average of 21·4 per excursion has only been exceeded once before.

The collecting, though not including anything new, was always satisfactory.

The thanks of the Club are due to the Secretary of the Royal Botanic Gardens and to the Metropolitan Water Board for permission to visit their enclosures; also to the Port of London Authority and Mr. Carlyle, who so kindly entertained the members at tea after their visit to the Surrey Commercial Docks. Later in the year a party of members gave an exhibition of Pond Life at the Dock Club and Institute, on which occasion Messrs. Soar, Offord and Wilson gave short lectures with lantern illustrations.

The Hon. Librarian and his assistant have expended a considerable amount of time and labour upon the classification and arrangement of the Club's books, and great progress has been made with the preparation of the new catalogue. The amount allotted to the cost of binding has been exceeded by £5, and repairs and cases for loose parts have cost about £11. The question of the elimination of periodicals containing nothing of particular interest to microscopists is before your Committee; the limitation of space for housing the Club's books being a difficulty that it has to meet. The Library has been used in 1912 as much as in previous years, but the cost of housing relatively to the use that is made of the books presents quite a serious problem for consideration by your Committee.

During the year under review the following volumes have been added :—

LIST OF BOOKS PURCHASED SINCE APRIL 1912.

Susswasserfauna Deutschlands:

Part II. Copepoda, Ostracoda, Malacostraca.
„ XIV. Rotatoria and Gastrotricha.

Science of the Sea. Edited by G. H. Fowler. Issued by the *Challenger* Society.

Huyghen's Treatise on Light. Translated by Prof. Silvanus P. Thompson.

Also fifty copies of Henry Sidebottom's paper, "Lagenae of the South-West Pacific Ocean," reprinted from the *Q. M. C. Journal*, April 1912, Vol. XI. These copies may be purchased at 2*s.* 6*d.* each.

LIST OF BOOKS PRESENTED SINCE APRIL 1912.

Presented by the Author, E. Penard:

Notes sur quelques Sarcodinés. Part I.

Presented by R. T. Lewis:

Objects for the Microscope. 2nd Ed. . . L. Lane Clark.

Presented by Julius Rheinberg:

Spectrum Method of Colour Photography.

Presented by the Author, Prof. E. A. Minchin:

Introduction to Study of Protozoa.

Presented by James Motham:

List of the Fossil Radiolaria from Barbados. A. Earland.
Figured in Ehrenberg's Fortsetzung.

Radiolaria . . . . . A. Earland.
Reprinted from the *Q. M. C. Journal*, April 1900.

Presented by Mrs. D. Wesché:

Phylogeny of the Nemocera . . . W. Wesché.
With notes on the leg bristles, hairs and certain mouth glands of Diptera.

Presented by the Author, E. PENARD:

NOTES SUR QUELQUES SARCODINÉS. Part II., 1906.

Presented by the Author, DR. J. B. DE-TONI:

SYLLOGE ALGARUM:

Vol. I. Sections I. and II. Chlorophyceae.
,, II. Bacillarieae.
,, III. Fucoideae.
,, IV. Sections I., II., III., IV., Florideae.
,, V. Myxophyceae.

Presented by the Author, C. E. HEATH:

BEGINNERS' GUIDE TO THE MICROSCOPE.

During the year ending December 1912 the Library has received the following publications:

Quarterly Journal of Microscopical Science.
Victorian Naturalist.
Mikrokosmos.
Royal Microscopical Society.
British Association.
Royal Institution.
Geologists' Association.
Manchester Literary and Philosophical Society.
Hertfordshire Natural History Society.
Bristol Naturalists' Society.
Birmingham Natural History and Philosophical Society.
Botanical Society of Edinburgh.
Glasgow Naturalists' Society.
Croydon Natural History Society.
Indian Museum (Calcutta).
Royal Society of New South Wales.
American Microscopical Society.
Smithsonian Institution.
Academy of Natural Science, Philadelphia.
Missouri Botanic Garden.
Philippine Journal of Science.
Bergen Museum.
Lloyd Library, Cincinnati.

U.S. National Herbarium.
Royal Society. Series B.
Natural History Society of Glasgow.
Zoologisch-botanischen Gesellschaft, Wien.
Redia.
U.S. National Museum.
Nuova Notarisia.
Nyt Magazin.
Birmingham and Midland Institute and Scientific Society.
Liverpool Microscopical Society.
Nova Scotian Institute of Sciences.
Royal Dublin Society.
Canadian Institute.
University of California.
Tijdschrift.
Illinois State Laboratory of Natural History.
Scottish Microscopical Society.

The Club's collection of slides has been increased by 133 preparations, including a further donation of fifty Freshwater Rhizopods from Dr. Penard. An interesting donation consisted of several fine injected anatomical preparations mounted by the late Sir Benjamin W. Richardson over fifty years ago, which are still in perfect condition. It is proposed to publish in future issues of the *Journal* lists of additions to the Cabinet, and these lists will serve as a supplementary catalogue of slides; the first list was published in the November issue. Two microscopes with several objectives and accessories were bequeathed to the Club by the late J. Mason Allen, so that the Club is now well provided with microscopes for exhibiting objects at the meetings.

The thanks of the Club are due as in former years to the editors of the *English Mechanic* and *Knowledge* for publishing excellent reports of the ordinary meetings. Those in the former journal are of great use in keeping country members *au courant* with the doings of the Club.

Your Committee desires to thank the officers for their services during the past year, and desires to call attention to the following resolution which was passed by them at their meeting on January 28th :—

"That the Committee accept with great regret the resignation

of Mr. W. B. Stokes as Secretary of the Club, and in so doing desire to express their hearty thanks to Mr. Stokes for his valuable services."

Your Committee sees nothing to prevent the Club maintaining its traditional usefulness. There is no question as to the need of such an institution; but there is need to remind members of the importance of the Club being all it seems to be to the new-comer, and not a cause of disappointment. The latter condition need never obtain if the dual rôle of the Club be maintained, presenting an effective means of publicity for the specialist and a help to the less experienced amateur.

THE TREASURER IN ACCOUNT WITH THE QUEKETT MICROSCOPICAL CLUB

DR. *For the year ending December 31st, 1912.* CR.

	£	s.	d.		£	s.	d.
To Balance from 1911	315	2	9	By Rent	75	0	0
„ Subscriptions 177 10 0				„ Expenses of *Journal*	180	1	4
„ 1 Life Composition 10 0 0				„ Postages, etc.	4	5	11
	187	10	0	„ Printing and Stationery	7	0	5
„ Dividends on Investments	12	14	4	„ Attendant	6	0	0
„ Sales of *Journal*	26	18	11	„ Petty Expenses	2	9	0
„ Sales of Catalogues	0	5	1	„ Books, etc.	21	15	4
„ Advertisements	9	9	0	„ *English Mechanic*	4	16	6
				„ Balance in hand	250	11	7
	£552	0	1		£552	0	1

INVESTMENTS.

	£	s.	d.
2½ per cent. Consols	100	0	0
Metropolitan Water Board Stock	100	0	0
Metropolitan Consolidated Stock	100	0	0
2½ per cent. Annuities, 1905	100	0	0

We have examined the above Statement of Income and Expenditure and compared the same with the Vouchers in the possession of the Treasurer, and have verified the Investments at the Bank of England, and find the same correct.

February 11th, 1913.

J. WILSON
J. RHEINBERG } *Auditors.*

FREDK. J. PERKS, *Treasurer.*

ON SOME FORAMINIFERA FROM THE NORTH SEA DREDGED BY THE FISHERIES CRUISER "HUXLEY" (INTERNATIONAL NORTH SEA INVESTIGATIONS—ENGLAND).

By Edward Heron-Allen, F.L.S., F.G.S., F.R.M.S., and Arthur Earland, F.R.M.S.

(*Read March 25th*, 1913.)

Plates 10, 11.

In connexion with our paper on the distribution of *Psammosphaera* and *Saccammina* in the Northern Area of the North Sea,* Mr. J. O. Borley, M.A., of the Fisheries Department, Board of Agriculture (England), suggested a continuation of our investigations into the Southern Area. With some reluctance we undertook the work, having little expectation of any tangible results, as Mr. Borley had already, from his personal experience of dredging in these waters, confirmed the generally held belief that rhizopodal life was of very sparing occurrence in the area in question. The shallowness of the sea and the consequently excessive wave action in this area were thought to be factors limiting the development of rhizopodal life, as compared with the conditions in the Scottish North Sea, where the average depth is greater and the disturbance due to the action of waves and currents is consequently less.

By the courtesy of the officers of the Board the dredgings made by the Fisheries Cruiser "*Huxley*" were placed at our disposal, and, guided by the admirable charts plotted by Mr. Borley to show the distribution of "silt areas" in the North Sea, six

* "On some Foraminifera from the North Sea, etc., dredged by the Fisheries Cruiser "*Goldseeker*" (International North Sea Investigations—Scotland). II. On the distribution of *Saccammina sphaerica* (M. Sars) and *Psammosphaera fusca* (Schulze) in the North Sea." *Journ. R. Micr. Soc.* 1913, pp. 1–26, pls. i.–iv.

dredgings were selected, three from the most northerly area dredged by the "*Huxley*," and three from an area considerably farther south.

The three Northerly Stations selected lie far to the N.E. of the Dogger Bank, in the centre of the North Sea, and in what is, strictly speaking, the Scottish area of that sea. They lie in the neighbourhood of the Great Fisher Bank, and are contiguous to the most southerly line of "*Goldseeker*" Stations (Stns. 41^{C}, 41^{B}, 41^{A}, 42, etc.) but farther out to sea towards the east. These three stations are referred to in the following paper as the Northern or Outer Area.

The three Southern Stations selected lie in the deep trough of water between the Dogger Bank and the Northumbrian coast, and are quite close to the shore. They are referred to in the paper as the Southern or Inner Area.

These dredgings were carefully selected with the view of obtaining the muddiest deposits possible, such conditions being most favourable for rhizopodal life; and they probably represent the richest of the "*Huxley*" dredgings, all the others which were cursorily examined consisting of clean siliceous sand with hardly any trace of microzoa. Such deposits, Mr. Borley assures us, are typical of the greater part of the Southern North Sea.

Owing to the widely separated stations selected the microfauna of these six dredgings may probably also be regarded as typical of the inshore and midsea areas. The comparative richness of the fauna of the Southern Area, as compared with the Northern, is undoubtedly due to the proximity of the coastline and the abundant food supply derived from the coastal deposits.

All the dredgings consisted of loose sands containing a considerable amount of mud; but whereas the sands from the Northern Area were easily cleaned (like the majority of the "*Goldseeker*" dredgings from adjacent stations), the sands of the Southern Area proved somewhat refractory. They contained numerous pellets of hardened mud which resisted disintegration, and even the action of a strong solution of boiling

soda did not completely remove the adherent mud from the sand-grains and foraminifera.

This is a noticeable feature, because as a rule muddy dredgings are readily broken down if thoroughly dried before the cleaning process is commenced, and even the most stubborn muds generally succumb to the action of boiling soda.

We have, however, met with similarly refractory muds at a few of the "*Goldseeker*" stations in the Moray Firth, and are unable to satisfy ourselves as to the cause of this viscosity, which is quite possibly due to different causes in separate localities. Among the various explanations which have occurred to us are:

1. The presence of the Hag (*Myxine glutinosa*). This loathsome fish is very common at some of the "*Goldseeker*" stations where the viscosity has been observed, and as when captured or touched it exudes an incredible quantity of slime, it is quite possible that the presence of this fish in any numbers might locally influence the nature of the sea-bottom. But Mr. Borley tells us that *Myxine* is rare in the vicinity of the Stations sampled, so it may be dismissed from consideration so far as the "*Huxley*" material is concerned.

2. Chemical changes in the mud owing to its having passed through the digestive organs of worms and Echinoderms, many of which obtain their nutriment by swallowing mud and extracting the organic matter. Thus, in the deep water of some of the Norwegian fjords, the bottom deposit consists of a very fine mud full of the tests of rhizopods and swarming with Annelids. When the mud is dried and broken down again in water, and the foraminifera have been removed by floating and elutriation, a mass of fine granular material is left which under the microscope proves to consist of small oval pellets of mud, the excreta of worms (Pl. 11, fig. 2).* These pellets resist the action of soda, making it evident that the mud must have become altered,

* Such deposits are presumably similar to those referred to by Dr. Johan Hjort under the name of "coprolitic muds." See *The Depths of the Ocean*, by Dr. J. Hjort and Sir John Murray (1912), p. 148.

or at any rate that the separate particles must have become agglutinated during their passage through the alimentary canals of the worms. Annelid remains are of fairly frequent occurrence in the "*Huxley*" dredgings from the Southern Area, but not noticeably so.

3. It is a matter of common knowledge that fresh mud or clay, if dried, breaks down readily in water; but that, if it is worked or "puddled" before being dried, it becomes plastic, and then resists disintegration. It is possible that wave or current action might thus serve to cover the surface of sand-grains and foraminifera with a coating of mud in a plastic or colloidal condition, and on the whole we are inclined to favour this explanation, so far as the viscosity of the "*Huxley*" deposits is concerned.

The whole question, however, though interesting from the point of view of the chemist and physicist, lies rather outside the province of the zoologist, although it seems evident that the phenomenon might be of great importance from the geological point of view, as such viscosity would favour the preservation of the encrusted microzoa.

A very noticeable feature in the "*Huxley*" dredgings is the roundness of the sand-grains as compared with those of "*Goldseeker*" dredgings from similar deposits. This is conclusive evidence that the grains have travelled a great distance, or have been subjected to tidal action within restricted geographical limits for a prolonged period in comparatively shallow water. The phenomenon has been observed in connexion with the Goodwin Sands. The scour of the tides and currents round the Dogger and Great Fisher Banks is doubtless the cause of the rotundity of the "*Huxley*" sands, the individual grains of which are often as smooth and polished as the Aeolian sands of the desert (Pl. 11, fig. 3).*

* Laboratory experiments have proved that a quartz grain $\frac{1}{50}$ in. in diameter requires an amount of abrasion equal to that acquired in travelling a distance of 3,000 miles in water before it becomes rounded to the form of a miniature pebble. (Daubrée, *Géologie Experimentale*, Paris,

To return to the microscopical investigation of the "*Huxley*" material: as already stated, this was originally undertaken solely with the view of extending our study of the distribution of two species, viz. *Psammosphaera fusca* (Schulze) and *Saccammina sphaerica* (M. Sars), and the results, so far as they affect those species, have already been published in our paper dealing with these forms.* But in the course of an examination of the material we found so many other forms that we determined to make a systematic list of the species recorded. This list, which we now publish, contains no less than 133 species or varieties, many of which have not been recorded previously from the areas in question.

It must not be concluded, from the occurrence of so extended a list, that the material was rich in foraminifera. So far from this being the case, the majority of the dredgings, previous to manipulation, gave little or no striking indication of organic remains beyond the presence of a few shell-fragments, spines of Echinoderms, annelid tubes, and an occasional rhizopod. The dredgings quite justified in superficial appearance the opinion which Mr. Borley and other zoologists familiar with the North Sea had formed, viz. that it was practically devoid of foraminifera. But careful and repeated elutriations of the dredgings resulted in the separation of small quantities of light material at each station, and, as is often the case, these minute samples yielded a more diverse fauna than is often found in richer gatherings. Except in the case of a few dominant species, however, the number of actual specimens observed was very small. Even in the case of the dominant species the proportion of individuals observed to the total bulk of the dredging was too insignificant to be estimated. The relative abundance of the species in the

1867, p. 47, and Phillips, *Q. J. Geol. Soc.*, vol. xxxvii., p. 21). But the dynamics of the troubled waters of the North Sea are probably quite different from the controlled action of a revolving cylinder in a laboratory experiment!

* *Journ. R. Micr. Soc.*, 1913, p. 25.

annexed lists, as indicated by the letters C, R, V R, etc., must be understood to refer to their abundance as inter-contrasted with other foraminifera, and not to their frequency in the whole bulk of the dredging.

A noticeable feature in the dredgings of the Southern or Inner Area is the relative frequency of specimens of fossil foraminifera. They are principally small types derived from cretaceous strata and such as are commonly found in shore sands and shallow-water dredgings round the southern coasts of England. But a few larger and well-developed fossil specimens of *Nodosaria* and *Cristellaria* were noted in Hauls 869 and 871, which are not cretaceous. These are perhaps derived from the Crag, a submarine outcrop of which formation is believed to extend across the North Sea * ; but they are not all deeply stained with iron, as is usually the case with the larger foraminifera of the Crag, and may be derived from the Gault.

Only one fossil was recorded from the Northern Area, viz. *Spiroloculina impressa* Terquem. This is no doubt derived from some submerged Tertiary deposit. It may be noted that Tertiary foraminifera have been dredged by the "*Goldseeker*" in the Moray Firth.

The fossils recorded are:

Spiroloculina impressa Terquem, Northern Area, one specimen.
Textularia globulosa Ehrenberg, Southern Area, all stations.
Nodosaria pauperata d'Orbigny, Southern Area, two stations.
Nodosaria plebeia Reuss, Southern Area, one station.
Cristellaria costata Fichtel and Moll sp., Southern Area, one specimen.
Cristellaria rotulata Lamarck sp., Southern Area, one station.
Globigerina aequilateralis Brady, Southern Area, one station.
Globigerina cretacea d'Orbigny, Southern Area, two stations.

* The appearance of many shell fragments dredged from a band of the sea bed stretching roughly from the Suffolk coast to the Continent suggests that they come from the Crag. These, however, are iron-stained and curiously glazed in appearance in some, but not in all cases, owing to attrition.

One of these species, viz. *Cristellaria rotulata* Lamarck sp., was also recorded as a recent form.

An examination of the list of species at the different stations reveals several noticeable features. Taking the three stations in the Northern Area first, it will be seen that they vary greatly in richness, Haul 767 yielding only 14 species, as against 26 in Haul 770 and 54 in Haul 772. Even the richest haul in the Northern Area contrasts badly with the poorest haul in the Southern Area, which yielded 72 species, the other Southern hauls yielding 79 and 94 species respectively.

This discrepancy is largely explained by the abundant records of the Family Lagenidae in the Southern Area. The figures are very striking, fossils being disregarded:

	Northern Area.	Southern Area.
Lagena	8	30
Nodosaria . . .	—	3
Lingulina . . .	—	1
Marginulina . . .	—	1
Vaginulina . . .	—	1
Cristellaria . . .	—	2
Polymorphina . . .	2	4
Uvigerina . . .	2	2
	—	—
Total . . .	12	44

The abundance of Lagenidae in this Area off the Northumberland coast has already been noted by Brady.* But in the "*Huxley*" dredgings only the genus *Lagena* is noticeably abundant, the other genera of the family not being well represented.

The other families exhibit a similar discrepancy in the lists of species recorded from the two Areas, but it is not so noticeable as in the case of the Lagenidae.

* *Report British Association*, 1862, p. 122; also *Trans. Tyneside Naturalists' Field Club*, 1863, vol v., part 4, p. 292; *Ibid.*, 1864, vol. vi., part 2, p. 194.

The dominant forms in the two Areas are as follows * :

	Northern.	Southern.
8.	*Miliolina seminulum* Linné sp.	*Miliolina seminulum* Linné sp.
21.	*Reophax scorpiurus* Montfort.	*Reophax scorpiurus* Montfort.
26.		*Haplophragmium pseudospirale* Will. sp.
37.	*Verneuilina polystropha* Reuss sp.	*Verneuilina polystropha* Reuss sp.
42.	*Bulimina fusiformis* Will.	*Bulimina fusiformis* Will.
69.		*Lagena laevigata* Reuss sp.
82.		*Lagena striata* d'Orbigny sp.
97.	*Polymorphina compressa* d'Orbigny.	
100.	*Polymorphina sororia* Reuss.	
106.		*Globigerina rubra* d'Orbigny.
118.	*Truncatulina lobatula* W. & J. sp.	*Truncatulina lobatula* W. & J. sp.
123.	*Rotalia Beccarii* Linné sp.	V C at one station only.
124.		*Rotalia orbicularis* d'Orbigny.
126.	*Nonionina depressula* W. & J. sp.	*Nonionina depressula* W. & J. sp.
132.	*Polystomella striatopunctata* F. & M. sp.	*Polystomella striatopunctata* F. & M. sp.

Several of these forms are more abundant in one Area than in the other, as may be seen by reference to the table.

Some of the discrepancies in the above comparative list can be explained by what we know of the distribution of the species in other rhizopodal faunas. Thus (**26**) *Haplophragmium pseudospirale* Will. sp. (Pl. 10, fig. 2-4) appears to be confined to coastal deposits. It is very common in many muddy shallow-water dredgings round the W. coast of Ireland and Scotland and in the Shetlands, but the "*Goldseeker*" records in the North Sea are

* The numbers refer to the tabular list at the end of the paper.

very few and entirely confined to coastal gatherings. It does not occur in any of the midsea "*Goldseeker*" dredgings from stations adjacent to the Northern Area of the "*Huxley*."

Of the other species recorded in the list a few have more than a passing interest. (1) *Nubecularia lucifuga* Defrance is a southern form, not previously recorded on the S. and E. coast of Britain beyond Bognor, Sussex. A few specimens have been dredged by the "*Goldseeker*" in the Moray Firth and Shetland seas, and these two records, from intermediate localities, are therefore of interest.

The same remarks apply to (9) *Massilina secans* d'Orbigny sp. This is the most abundant and typical Miliolid of the shore sands and shallow water all round the S. and W. coast-line. There are few records of shore sands on the E. coast, but the species occurs at Cromer and St. Andrews (Fife) and is abundant at Scapa in Orkney in shore sand. It is extremely rare in the "*Goldseeker*" North Sea dredgings, but the few specimens found were from a Station (39[B]) near the "*Huxley*" Northern Area. Its absence from the Southern Area is noticeable, and probably due to the muddiness of the deposit.

(12) *Cornuspira striolata* Brady. The specimen from Haul 767 (Northern Area) is of the very fragile and etiolated type abundant in many of the "*Goldseeker*" dredgings from the deeper North Sea.

(13) *Cornuspira diffusa* Heron-Allen and Earland* (Pl. 11, fig. 1). The specimens of this form, which has been recently described by us, were large and quite typical, but few in number. The Northern Area is quite close to the "*Goldseeker*" Stations at which it is most abundant, but the species is sparingly distributed round the British coast.

(14) *Bathysiphon argenteus*, (62) *Lagena cymbula* (Pl. 10, figs. 10–12), (84) *Lagena unguis*, and (117) *Discorbina Praegeri*

* "On some Foraminifera from the North Sea, etc., dredged by the Fisheries Cruiser "*Goldseeker*" (International North Sea Investigations—Scotland). III. On *Cornuspira diffusa*, a new type from the North Sea." *Journ. R. Micr. Soc.*, 1913, pp. 272–6, pl. xii.

are new forms discovered first by us in "*Goldseeker*" dredgings. They are described and figured in our report on the Foraminifera of the Clare Island Survey (*Proc. Roy. Irish Acad.*, 1913, vol. xxxi., No. 64).

(**20**) *Reophax nodulosa* Brady (Pl. 10, fig. 1) is extremely rare as a British species. It has been recorded from the Clyde Area and Skye by Robertson and from the Estuary of the Dee by Siddall. The British specimens are very minute, but in the deep sea it attains a great size, up to 1 in. in length.

(**23**) *Haplophragmium anceps* Brady, another deep-water form, is of rare occurrence in British waters. It has been recorded from shore sands at Southport (Chaster) and Bognor (Earland), and we have recently dredged it in the Clare Island Area.

(**25**) *Haplophragmium crassimargo* Norman (Pl. 10, fig. 5–6), a large and very robust form closely allied to *H. canariense* d'Orbigny sp., is the typical *Haplophragmium* of the deeper parts of the North Sea, and is abundant in many of the "*Goldseeker*" dredgings.

(**27**) *Thurammina papillata* Brady. The single specimen recorded from Haul 869 in the Southern Area is extremely small, but quite typical of the spherical type (cf. Brady, *Foraminifera of the "Challenger,"* 1884, pl. xxxvi., fig. 7). The papillae are prominent and very numerous. The genus *Thurammina* is abundant and very variable in the deep water of the North Sea to the N.E. of Shetland, but very rare in the central North Sea.

(**28**) *Ammodiscus incertus* d'Orbigny. All the specimens are very minute and of a light-grey colour. The genus is very sparingly distributed in all the "*Goldseeker*" dredgings from the North Sea, and all the specimens are minute. In the Faroe Channel, however, it attains its full dimensions.

(**35**) *Spiroplecta biformis* Parker and Jones sp. (Pl. 10, fig. 9). The single specimen of this rare form, recorded from Haul 772 in the Northern Area, is noticeable for the rapid increase in size of the Textularian chambers following the Spiroplectine portion of the test.

(37) *Verneuilina polystropha* Reuss sp. All the specimens of this species, one of the most abundant and typical North Sea forms, belong to the large coarsely built type, except in Haul 770 Northern Area, where also a few individuals of the minute and delicate type described and figured by us in the Clare Island Survey Report were observed.

(38) *Clavulina obscura* Chaster (Pl. 10, figs. 7, 8), occurs in both Areas, but whereas the Northern Area yielded only a single specimen, the species attains an extraordinary development both as regards size and abundance in Haul 871 in the Southern Area. It is usually a very rare species, though widely distributed round our coasts in muddy gatherings.

(91) *Lingulina carinata* d'Orbigny. The single specimen from Haul 869 Southern Area is of a minute type. Such specimens occur sparingly in most of the "*Goldseeker*" dredgings from muddy areas.

(92) *Marginulina glabra* d'Orbigny. The single specimen from Haul 871 is very minute. But the species is abundant and attains a very large size in the deeper waters of the North Sea to the N.E. of Shetland.

(106) *Globigerina rubra* d'Orbigny (Pl. 10, figs. 13–15). This species is one of the commonest Globigerinae all over the North Sea and often forms a large proportion of the finer material dredged on muddy bottoms.

(110) *Discorbina Chasteri* Heron-Allen and Earland. Originally described by the late Dr. Chaster of Southport under the specific name *Discorbina minutissima*. This specific name having been previously used by Seguenza for another form, we have (in the Report on the Foraminifera of the Clare Island Survey) renamed the species after its original discoverer. It is of common occurrence in muddy dredgings from all the shallow coastal deposits of the North Sea and around the Western shores of Britain generally.

(112) *Discorbina Mediterranensis* d'Orbigny sp. and (115) *Discorbina Peruviana* d'Orbigny sp. are old species which we propose

to revive for sub-types of the "*rosacea*" group, under a scheme which is fully explained in our Clare Island Report.

(**133**) *Polystomella crispa* Linné sp. The occurrence of only a single specimen of this species in the Southern Area is very noticeable, as it might have been expected to occur more plentifully so near the coast. But as regards the single specimen from the Northern Area, its occurrence there is still more noteworthy, as the species is extremely rare in the "*Goldseeker*" dredgings even in the proximity of the coast and none have been previously found so far out at sea as this. The specimen is, however, very water-worn, and may have been current-borne for a great distance.

List of "Huxley" Stations from which Material was Examined.

A. Northern or Outer Area—lying N.N.E. of the Dogger Bank.

1. Haul 767, Station xix., 56° 53′ N., 3° 43′ E. Dredging made July 22nd, 1906, in 35 fathoms, to the S.W. of the Great Fisher Bank.
2. Haul 770, Station xxii., 56° 50′ N., 3° 59′ E. Dredging made July 24th, 1906, in 31 fathoms, on the Inner Shoal to the S. of the Great Fisher Bank.
3. Haul 772, Station xxv., 56° 34′ N., 3° 53′ E. Dredging made July 24th, 1906, in 37 fathoms, to the S. of the Inner Shoal and Great Fisher Bank.

B. Southern or Inner Area—lying W. of the Dogger Bank, between the Bank and the English coast.

4. Haul 869, Station xlii., 55° 6′ N., 1° 2′ W. Dredging made July 23rd, 1907, in 43 fathoms, off Blyth, Northumberland.
5. Haul 871, Station xliv., 54° 59′ N., 1° 7′ W. Dredging made July 23rd, 1907, in 34 fathoms, off Tynemouth.
6. Haul 882, Station (?), 55° 21′ N., 1° 10 ′W. Dredging made July 26th, 1907, in 45 fathoms, off Alnmouth.

The asterisk denotes the presence of fossil specimens. 1 = a single specimen only. V C = very common. C = common. F = frequent. R = rare. V R = very rare.

	Haul 767.	Haul 770.	Haul 772.	Haul 869.	Haul 871.	Haul 882.
	1	2	3	4	5	6
MILIOLIDAE.						
Sub-family *NUBECULARINAE.*						
1. *Nubecularia lucifuga* Defrance			1		1	
Sub-family *MILIOLININAE.*						
2. *Biloculina depressa* d'Orbigny					F	
3. *Biloculina ringens* Lamarck sp.					R	
4. *Spiroloculina impressa* Terquem			1*			
5. *Miliolina bicornis* Walker & Jacob sp.						V R
6. *Miliolina circularis* Bornemann sp.			C		R	
7. *Miliolina contorta* d'Orbigny sp.				1	2	
8. *Miliolina seminulum* Linné sp.	V C	V C	V C	2	V C	V C
9. *Massilina secans* d'Orbigny sp.			2			
Sub-family *PENEROPLIDINAE.*						
10. *Cornuspira involvens* Reuss					1	1
11. *Cornuspira Selseyensis* Heron-Allen & Earland						1
12. *Cornuspira striolata* Brady	1					
13. *Cornuspira diffusa* Heron-Allen & Earland			F			
ASTRORHIZIDAE.						
Sub-family *PILULININAE.*						
14. *Bathysiphon argenteus* Heron-Allen & Earland				V R		V R
Sub-family *SACCAMMININAE.*						
15. *Psammosphaera fusca* Schulze	C	V R	V C	R	V C	
16. *Saccammina sphaerica* M. Sars				F		C
Sub-family *RHABDAMMININAE.*						
17. *Hyperammina ramosa* Brady			R			
LITUOLIDAE.						
Sub-family *LITUOLINAE.*						
18. *Reophax difflugiformis* Brady			1			
19. *Reophax fusiformis* Williamson sp.		F	V C		V R	
20. *Reophax nodulosa* Brady						1
21. *Reophax scorpiurus* Montfort	V C	R	V C	V C	V C	V C
22. *Reophax Scottii* Chaster			F	V R	F	C
23. *Haplophragmium anceps* Brady					1	
24. *Haplophragmium Canariense* d'Orbigny sp.			1	V R	C	1
25. *Haplophragmium crassimargo* Norman	1		1			
26. *Haplophragmium pseudospirale* Williamson sp.				V C	V C	V C

	Haul 767.	Haul 770.	Haul 772.	Haul 869.	Haul 871.	Haul 882.
	1	2	3	4	5	6
Sub-family *Trochammininae.*						
27. *Thurammina papillata* Brady				1		
28. *Ammodiscus incertus* d'Orbigny sp.		R	F			
29. *Trochammina ochracea* Williamson sp.		F	C	R	V C	
30. *Trochammina squamata* Jones & Parker					F	V C
Textularidae.						
Sub-family *Textularinae.*						
31. *Textularia agglutinans* d'Orbigny					V R	
32. *Textularia conica* d'Orbigny				V R	V R	V C
33. *Textularia globulosa* Ehrenberg				F*	F*	1*
34. *Textularia gramen* d'Orbigny					V R	
35. *Spiroplecta biformis* Parker & Jones sp.			1			
36. *Gaudryina filiformis* Berthelin					F	R
37. *Verneuilina polystropha* Reuss sp.	V C	R	V C	V C	V C	V C
38. *Clavulina obscura* Chaster			1	F	V C	
Sub-family *Bulimininae.*						
39. *Bulimina aculeata* d'Orbigny				V R	R	C
40. *Bulimina elegans* d'Orbigny				F	C	R
41. *Bulimina elegantissima* d'Orbigny			C	R	F	
42. *Bulimina fusiformis* Williamson	V C	C	V C	V C	V C	V C
43. *Bulimina marginata* d'Orbigny	C	F	C	F	F	C
44. *Bulimina ovata* d'Orbigny				F		
45. *Bulimina pupoides* d'Orbigny			R	R	1	
46. *Virgulina Schreibersiana* Czjzek			R			R
47. *Bolivina difformis* Williamson sp.				V R	V R	1
48. *Bolivina dilatata* Reuss				R	C	C
49. *Bolivina nobilis* Hantken					1	1
50. *Bolivina plicata* d'Orbigny			1	V R	F	F
51. *Bolivina punctata* d'Orbigny			C	R	F	F
52. *Bolivina textilarioides* Reuss			R			
53. *Bolivina variabilis* Williamson sp.				R	F	
Sub-family *Cassidulininae.*						
54. *Cassidulina crassa* d'Orbigny			F	F	F	F
55. *Cassidulina laevigata* d'Orbigny		V R	R		1	
56. *Cassidulina subglobosa* Brady			R	R	F	
Lagenidae.						
Sub-family *Lagenidae.*						
57. *Lagena acuticosta* Reuss		V R				
58. *Lagena apiculata* Reuss sp.					V R	2
59. *Lagena bicarinata* Terquem sp.				1		
60. *Lagena clavata* d'Orbigny sp.				R	C	F
61. *Lagena costata* Williamson sp.					F	R
62. *Lagena cymbula* Heron-Allen & Earland				1		
63. *Lagena distoma* Parker & Jones			1	R	C	V C
64. *Lagena fasciata* Egger			R	V R		1
65. *Lagena globosa* Walker & Jacob sp.			1	V R	F	1
66. *Lagena gracillima* Seguenza sp.				1	C	

	Haul 767.	Haul 770.	Haul 772.	Haul 869.	Haul 871.	Haul 882.
	1	2	3	4	5	6
67. *Lagena gracilis* Williamson				VR	1	1
68. *Lagena hexagona* Williamson sp.				VR	F	VC
69. *Lagena laevigata* Reuss sp.		VR	VC	C	VC	F
Lagena laevigata, trigonal form				VR		1
70. *Lagena laevis* Montagu sp.			1	R	C	1
71. *Lagena lagenoides* Williamson sp.					VR	
Lagena lagenoides, trigonal form.				1		
72. *Lagena lineata* Williamson sp.					F	1
73. *Lagena lucida* Williamson sp.		R	R	VR	F	F
74. *Lagena Malcomsonii* J. Wright				VR		
75. *Lagena marginata* Walker & Boys sp.					F	F
76. *Lagena marginato-perforata* Seguenza					1	
77. *Lagena Orbignyana* Seguenza sp.				VR	F	VC
78. *Lagena ornata* Williamson sp.				1		
79. *Lagena quadrata* Williamson sp.				VR	1	
80. *Lagena semistriata* Williamson				F	C	C
81 *Lagena squamosa* Montagu sp.					F	R
82. *Lagena striata* d'Orbigny sp.			1	VC	C	C
83. *Lagena sulcata* Walker & Jacob sp.				VR	C	1
84. *Lagena unguis* Heron-Allen & Earland					1	
85. *Lagena Williamsoni* Alcock sp.				F	C	C
Sub-family *Nodosarinae.*						
86. *Nodosaria filiformis* d'Orbigny					1	
87. *Nodosaria pauperata* d'Orbigny				1*	1*	
88. *Nodosaria plebeia* Reuss.					VR*	
89. *Nodosaria pyrula* d'Orbigny				R	1	
90. *Nodosaria scalaris* Batsch sp.					2	1
91. *Lingulina carinata* d'Orbigny				1		
92. *Marginulina glabra* d'Orbigny					1	
93. *Vaginulina legumen* Linné sp.				VR		
94. *Cristellaria acutauricularis* Fichtel & Moll sp.				1		1
95. *Cristellaria costata* Fichtel & Moll sp.				1*		
96. *Cristellaria rotulata* Lamarck sp.				R*	R	
Sub-family *Polymorphininae.*						
97. *Polymorphina compressa* d'Orbigny	VC	VC	VC	R	VC	1
98. *Polymorphina lactea* Walker & Jacob sp.					R	
99. *Polymorphina oblonga* Williamson				1		
100. *Polymorphina sororia* Reuss	C	VC	VC	R		
101. *Uvigerina angulosa* Williamson		F	1		R	F
102. *Uvigerina pygmæa* d'Orbigny			1	1		
Globigerinidae.						
103. *Globigerina aequilateralis* Brady					1*	
104. *Globigerina bulloides* d'Orbigny		F	R	C	R	C
105. *Globigerina cretacea* d'Orbigny				F*	1*	
106. *Globigerina rubra* d'Orbigny		F	1	VC	C	C
107. *Pullenia sphaeroides* d'Orbigny sp.						1

	Haul 767.	Haul 770.	Haul 772.	Haul 869.	Haul 871.	Haul 882.
	1	2	3	4	5	6
ROTALIDAE.						
Sub-family *SPIRILLININAE.*						
108. *Spirillina vivipara* Ehrenberg			F	V R	V R	1
Sub-family *ROTALINAE.*						
109. *Patellina corrugata* Williamson					C	C
110. *Discorbina Chasteri* Heron-Allen & Earland			1	1	R	1
111. *Discorbina globularis* d'Orbigny					C	1
112. *Discorbina Mediterranensis* d'Orbigny sp.		1			R	
113. *Discorbina nitida* Williamson sp.			F	V R	C	C
114. *Discorbina obtusa* d'Orbigny sp.			1	C	F	1
115. *Discorbina Peruviana* d'Orbigny sp.					C	
116. *Discorbina polyrraphes* Reuss						1
117. *Discorbina Praegeri* Heron-Allen & Earland						
118. *Truncatulina lobatula* Walker & Jacob sp.	V C	F	V C	F	C	R C
119. *Truncatulina refulgens* Montfort sp.					V R	F
120. *Truncatulina Ungeriana* d'Orbigny sp.		F	R			
121. *Pulvinulina haliotidea* Heron-Allen & Earland					F	1
122. *Pulvinulina Karsteni* Reuss sp.		R	C	R	V R	R
123. *Rotalia Beccarii* Linné sp.	C	C	C		V C	
124. *Rotalia orbicularis* d'Orbigny				V C		C
NUMMULINIDAE.						
Sub-family *POLYSTOMELLINAE.*						
125. *Nonionina asterizans* Fichtel & Moll sp.			R	V R	F	1
126. *Nonionina depressula* Walker & Jacob sp.	V C	V C	V C	C	F	F
127. *Nonionina pauperata* Balkwill & Wright					R	
128. *Nonionina scapha* Fichtel & Moll sp.				1	R	
129. *Nonionina stelligera* d'Orbigny					1	1
130. *Nonionina turgida* Williamson sp.				V R		F
131. *Nonionina umbilicatula* Montagu sp.				1		
132. *Polystomella striatopunctata* Fichtel & Moll. sp.	V C	V C	V C	R	V C	C
133. *Polystomella crispa* Linné sp.		1		1		

DESCRIPTION OF PLATES.

Plate 10.

Fig. 1. *Reophax nodulosa* Brady, × 120.
„ 2, 3, 4. *Haplophragmium pseudospirale* Will. sp., × 40.
„ 5, 6. *Haplophragmium crassimargo* Norman, × 30.
„ 7, 8. *Clavulina obscura* Chaster, × 100.
„ 9. *Spiroplecta biformis* Parker & Jones sp., × 120.
„ 10. *Lagena cymbula* Heron-Allen & Earland, superior view, × 250.
„ 11. *Lagena cymbula* Heron-Allen & Earland, inferior view, × 250.
„ 12. *Lagena cymbula* Heron-Allen & Earland, edge view, × 250.
„ 13, 14, 15. *Globigerina rubra* d'Orbigny, × 120.

Plate 11.

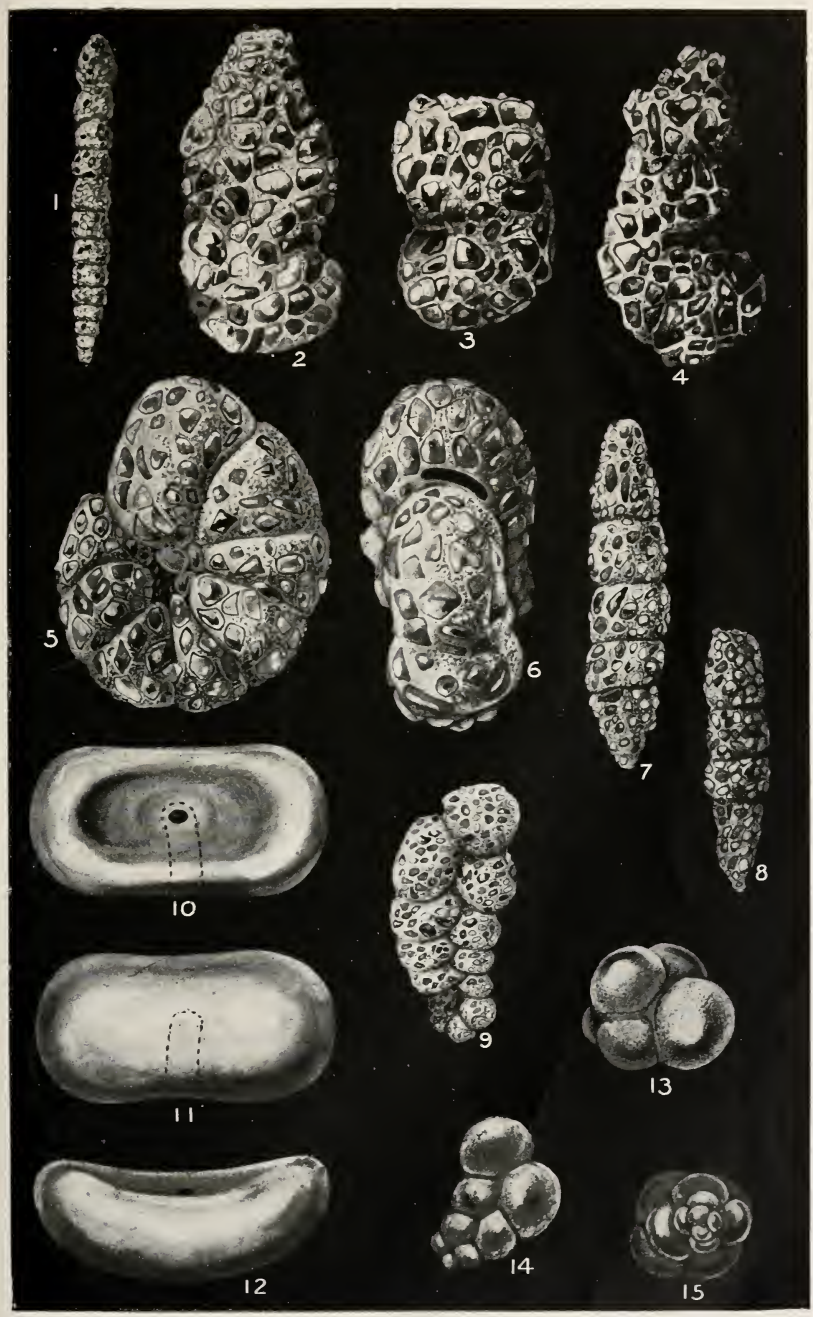
Fig. 1. *Cornuspira diffusa* Heron-Allen & Earland, × 5, illustrating the protean habit of growth.
„ 2. Heavy portion of ooze from Hilte Fjord, Norway, 260 metres, "*Goldseeker*" Haul 141, depth 260 metres. Most of the foraminifera have been removed by elutriation, leaving a residuum of faecal pellets of Annelid origin (? *Hyalinoecia* sp.) × 45.
„ 3. Rounded sand-grains from "*Huxley*" material, × 12.
„ 4. Normal angular grains typical of shore gatherings and shallow-water deposits, × 12.
„ 5. Crystalline sand-grains from a dredging in the Hauraki Gulf, New Zealand, × 12. Such crystalline grains are very rare except in the neighbourhood of volcanic deposits.

[It is greatly to be hoped that the writers will find it possible for them to examine in similar detail a certain number of the remaining "*Huxley*" dredgings, of which some six hundred are available, taken from the North Sea south of the Forth. Their present paper shows that in their practised hands results of considerable interest may be expected should this be done. I would

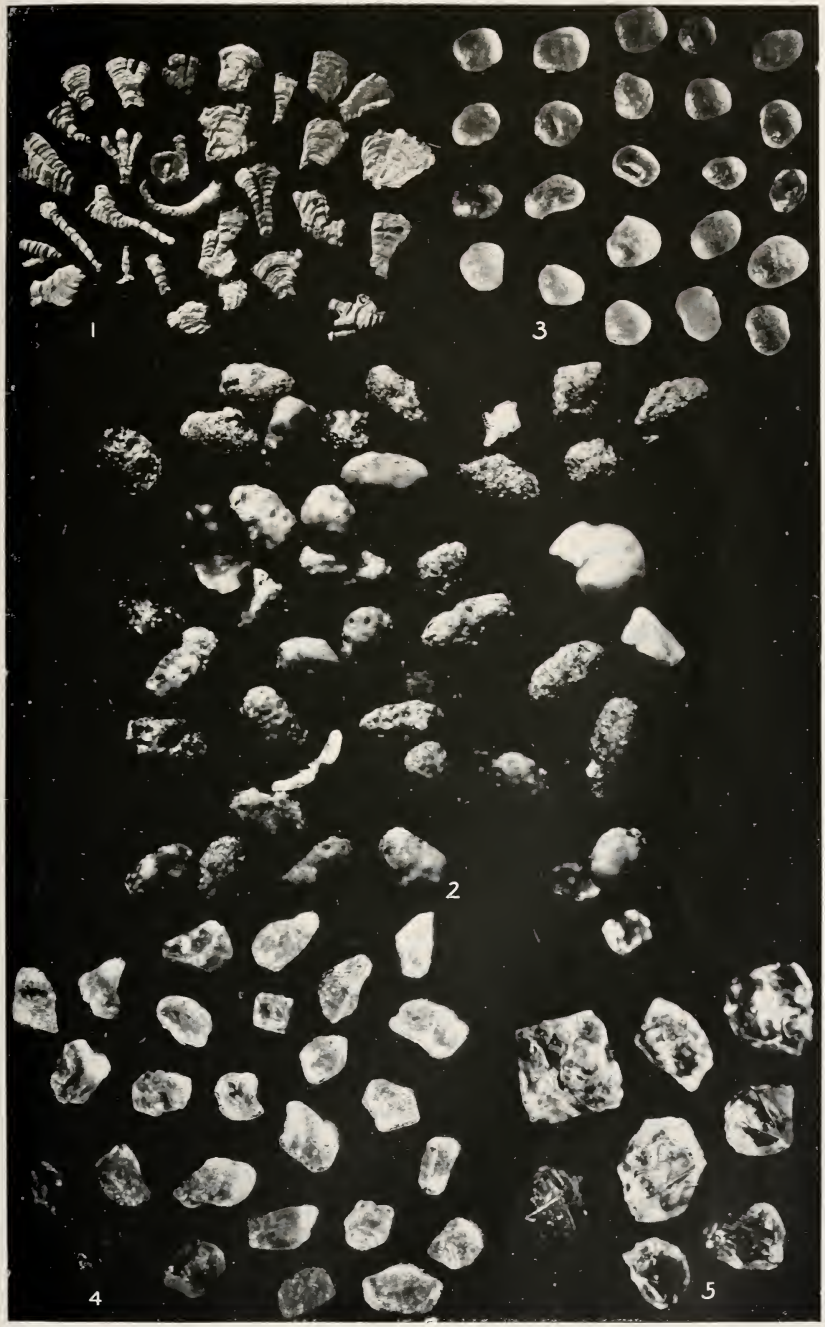
submit for their consideration the examination of selected stations along lines drawn east and west, in the manner of sections. A large proportion of these in all probability could be dealt with in a very summary manner, but the remainder might yield results of importance as to the relation of distribution to salinity, depth, temperature and current, possibly even affording evidence of the main trend of the currents, which would provide a welcome check on other observations carried out by current-meters and drift-bottles.

In regard to the samples which they have examined from the deep water east of the Dogger it may be remarked that the Admiralty tide charts show but low rates of velocity in the district, which has moreover a greater depth of water than one would expect to be consistent with frequent wave action at the bottom. Recent current measurements carried out by the Board of Agriculture and Fisheries have also failed to detect any marked resultant current. It may therefore be suggested that the sub-polish attained by the rounded grains is not in all cases due to attrition on the spot. The freedom of the adjacent Dogger Bank from silt, a grade of material found in high percentage on either side, may perhaps be explained by the finer particles churned up and held in suspension by wave action during storms being gradually washed into the deeper water: some segregation of the rounder grains may take place in the same manner. A thorough geological examination of the area, especially of the Scottish coast, might also show to what extent, if any, the grains result from the disintegration of certain definite sandstone rocks.

For the action of wave and current in the Southern Bight (North Sea south of 53°) the collection of samples as a whole furnish good evidence; the material is to a great extent graded as in a levigator, the average diameter of the sand particles diminishing as the speed of the current declines. Yet even in this district, with its shallower waters and far more powerful currents, the upper limit of size of the particles affected is soon reached, and one feels in consequence the need of searching for other causes before explaining the rotundity of certain of the grains near the Dogger by tidal action alone.—J. O. Borley.]



Foraminifera from the North Sea.



Cornuspira diffusa Heron-Allen and Earland.
Sand-grains, etc., from the Bottom-deposits,

DESCRIPTION OF *ARRHENURUS SCOURFIELDI* AND *ACERCUS LONGITARSUS*: TWO NEW SPECIES OF WATER-MITES.

By C. D. Soar, F.L.S., F.R.M.S.

(*Read April 22nd*, 1913).

Plates 12, 13.

Arrhenurus Scourfieldi sp. nov.

In the autumn of 1912, Mr. D. J. Scourfield handed me a tube containing a few water-mites, which he had taken from fresh water in Cornwall. Amongst them was one which was quite new to me, a male Arrhenurus, of the sub-genus Megalurus. As I cannot find that it has been described or figured, I propose to name it after Mr. Scourfield.

Arrhenurus Scourfieldi sp. nov.—The specimen is a male; length 1·04 mm., greatest breadth about 0·64 mm. In outline the body is long; anterior corners well cut off, and slightly bent inwards; sides almost straight, tapering towards the posterior margin. The posterior margin is divided by a central cleft into two well-rounded portions.

The skin is covered with small papillae; the dorsal surface has the usual indented sunk line common to members of this genus, and several dermal glands both inside and outside the sunken line. Looked at from above there is a small wing-like process about 0·15 mm. from the posterior margin.

The colour is a dark blue-green with brown markings on the dorsal surface. The epimera are slightly lighter in colour. It is of the same colour as *Arrhenurus globator*.

The eyes are very dark red, close to margin, about 0·32 mm. apart. Capitulum, about 0·20 mm. long.

The first pair of epimera are joined together at the back of the capitulum, the second pair pressed close to first pair so that what

is known as the first two pairs of the epimera form one distinct group.

The posterior pair are in two distinct groups placed about 0·05 mm. behind the second pair.

The genital area lies about 0·08 mm. behind the fourth pair of epimera, the plates stretching the whole distance across the body of the mite. The length of each plate is about 0·25 mm., tongue shaped and covered with numerous acetabula.

The legs are of the usual structure of the genus with the spur on the fourth segment of the fourth leg. They are strong and well provided with swimming hairs. The first leg about 0·60 mm. long, fourth leg 0·84 mm.

Locality : Near the Lizard, Cornwall, 1912. Female unknown.

Acercus longitarsus sp. nov.

Acercus longitarsus sp. nov.—The body is 0·76 mm. in length ; breadth about 0·54 mm., ovate. The colour is a pale straw yellow with dark-brown markings. There is a reddish-yellow wedge-shaped patch in the centre of the dorsal surface.

The epimera cover nearly the whole of the ventral surface, and differ from that of the type species *Acercus ornatus* in the following important particulars. Firstly, the genital area instead of being situated in a small bay on the posterior margin of the epimera as in *Acercus ornatus*, is partly enclosed in an angular space formed by the posterior edge of the epimera being turned at a low angle towards the median line. Secondly, near the base of the epimera are two small incurvations, one on each side, which are not found in the type species of this genus. They run into the epimera about 0·05 mm. The actual genital area itself is similar to type species, having six acetabula arranged in the same way.

The palpi are about 0·45 mm. in length. On the flexar edge of the fourth segment are placed two long hairs, a little distance apart ; they are close together in *Acercus ornatus*.

The legs of the species form the most striking departure from the type form and in fact all other species of this genus ; on comparison it will be seen that the tarsi are enormously developed in length.

The last segment of the first and second pairs of legs are longer

than usual, but it is the last segment of the fourth pair which shows the great increase in length. The tarsi measure as much as 0·60 mm., which is more than the fourth and fifth segment together.

The first leg is about 1·40 mm. in length, the second about 1·30, the third about 0·90, the fourth about 1·58.

The eyes, large and distinct, are very dark red and about 0·14 mm. apart.

This mite can be most easily recognised by the length of the tarsus of the fourth pair of legs. I propose naming it *Acercus longitarsus*.

Locality: South Devonshire (female unknown).

There are also one or two additions to be made to British records. Mr. Williamson, F.R.S.E., in working out the material on the Genus Sperchon, has found that we have two species quite new to the British area, and two that up to the present have only been recorded for Ireland.

1st. *Sperchon clupeifer* Pier.

Sub-genus: Hispidosperchon.

Locality: Oban and Norfolk Broads.

2nd. *Sperchon tenuabilis* Koen.

Sub-genus: Hispidosperchon.

Locality: Oban. Recorded for Ireland by Halbert in Clare Island survey.

3rd. *Sperchon papillosus* Sig Thor.

Sub-genus: Squamosus.

Locality: Oban. Recorded for Ireland by Halbert.

4th. *Sperchon Thienemanni* Koen.

Sub-genus: Rugosa.

Locality: Derbyshire.

Description of Plates.

Plate 12.

Fig. 1. *Arrhenurus Scourfieldi* sp. nov.—Dorsal surface of male drawn from a living specimen, × 50.

„ 2. *Arrhenurus Scourfieldi* sp. nov.—Ventral surface of same drawn after mounting.

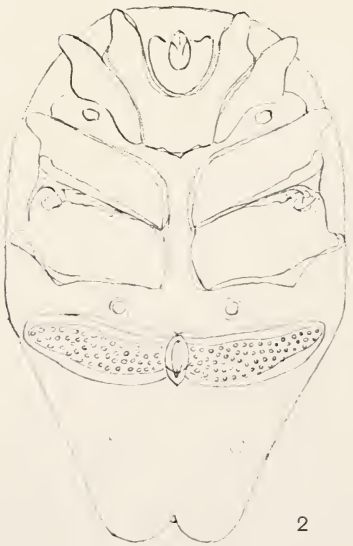
Plate 13.

Fig. 1. *Acercus longitarsus* sp. nov.—Dorsal surface of males, × 58.

„ 2. *Acercus longitarsus* sp. nov.—Ventral surface of same, × 58.

„ 3. *Acercus longitarsus* sp. nov.—Palpi of same, × 150.

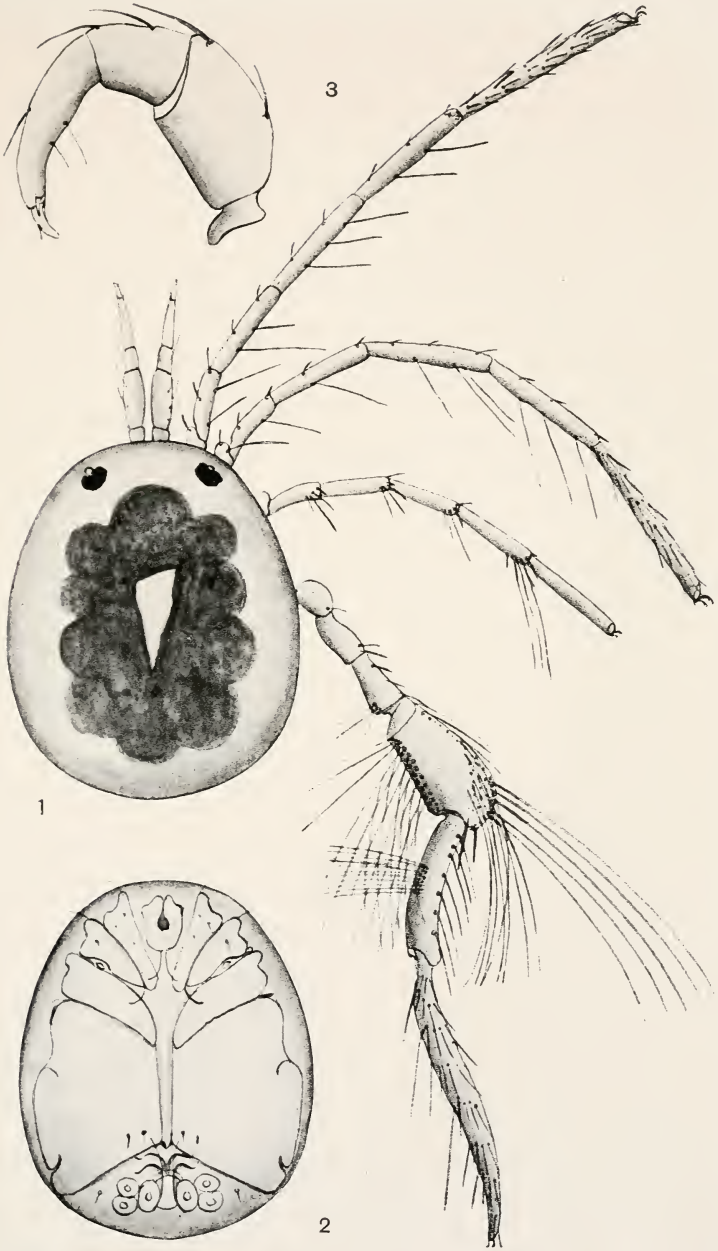
1



2

C. D. S., *del. ad nat.*

♂ *Arrhenurus Scourfieldi* sp. nov.



C. D. S., *del. ad nat.*

♂ *ACERCUS LONGITARSUS* sp. nov.

THE COLLECTION AND PRESERVATION OF THE HYDROIDA.

By G. T. Harris.

Communicated by C. J. H. Sidwell.

(*Read April 22nd*, 1913.)

The Hydroida are too well known, as both beautiful and interesting objects, to need any eulogy on my part. If they have received less attention from the members of the Q.M.C. than some other groups, it is probably due to the fact that the Hydroida evince a decided and conservative preference for salt water, and show no inclination whatever for the uneventful environment of metropolitan ponds. Hence, those who would collect them must seek them where they may be found, *i.e.* from tidal limits to as many fathoms as the collector's means or stomach will allow.

Bearing in mind that this paper is written more for the help of the novice than as a communication offering original matter, I would safeguard myself from any charge of carelessness by warning the uninitiated that collecting, say, rotifers, and collecting hydroids are two totally dissimilar things. Pond collecting is a more or less safe and a very pleasant recreation; hydroid collecting is rarely enjoyable, and may be, by a little carelessness, rendered adventurous. The one could be prosecuted in a silk hat and a frock coat if desired, without seriously giving the wearer away; the costume best suited to the other tries the loyalty of one's staunchest friend. Dredging is, perhaps, less open to contumely than shore collecting; the nature of the operation secures to the collector a considerable measure of privacy, while the examination of the spoil can be carried out in attitudes familiar to oneself and those around. Shore collecting permits of no compromise, and the positions most consonant with successful collecting are mainly such as contribute materially to the entertainment of the seaside visitor waiting to be amused.

I think it may be taken for granted that, in spite of its

obvious drawbacks, shore collecting will appeal to the amateur collector rather than the more professional method of dredging. It entails less expense, requires less intimacy with the local conditions, and, for a given amount of time expended, probably yields a richer harvest; finally, the physiological effects of shore-collecting are not so overwhelming as are those sometimes connected with dredging. At the same time, no serious student of the Hydroida can ignore the dredge as a means of collecting, as a large number of species can only be obtained by its aid. However, for the reassurance of those who confine themselves to shore collecting, I may state, as the result of long experience, that on a favourable shore the number of species to be found between tide-marks is very great, and amongst them are many of the most beautiful forms amongst the Hydroida.

Unfortunately no precise directions can be given for successful shore collecting. It is entirely a matter of experience, and even the practised collector may fail dismally until he has learnt the shore upon which he is engaged. Why hydroids should be found plentifully in a certain section of shore, yet be absent from the same shore a quarter of a mile away, with apparently the same conditions, I am unable to say, yet such appears to be the case. In my own district, where rock-pools are plentiful, I have a case in point. *Coryne vaginata*, one of the commonest littoral hydroids along the south coast, occurs in two or three of the larger pools of a certain locality, yet although the rock-pools to the right and left for some distance are, as far as I can see, identical, no Coryne occurs in them. Nor is this accidental, or peculiar to one season, as I have been able to go to these particular pools for the last six years with the certainty of obtaining *Coryne vaginata*. Some years ago when collecting at Criccieth, in North Wales, I spent day after day laboriously trying to collect hydroids where none grew; finally, I transferred my operations to a less likely looking section of the shore, and collected hydroids during the remainder of my visit over a very limited area. An instance singularly illustrative of this elusive quality of shore collecting recently came under my notice, which may serve to impress upon inexperienced collectors the desirability of not jumping too hastily to the conclusion that they are on a barren shore. A party of professional naturalists spent the whole of one summer in investigating the fauna of a certain

section of coast, the results of which were embodied in a report. The shore collecting was apparently confined to one spot, from which but one hydroid, and that the ubiquitous *Sertularia pumila*, was recorded; yet a quarter of a mile farther east is an exceptionally prolific hunting-ground at low tide, where at least a dozen species of hydroids may be taken. All this points to the fact that wherever the hydroid-hunter elects to collect he must, as a preliminary, first ascertain that he has found the hydroid ground. When he has satisfied himself that he has done so, then collecting may begin in earnest.

It is too readily assumed that only those shores are good for hydroid-hunting upon which rock-pools occur. My experience leads me to protest against this assumption, for I have often had much better collecting on shores strewn with large fucus-covered boulders than in some rock-pool districts. Rock-pools do not necessarily imply the existence in them of hydroids, not even when they are clean, sanitary abodes. The rock-pools at Sidmouth are excavated in Permian sandstone at the base of cliffs 500 ft. high, composed principally of Keuper marl, and in the early summer are lined, as is everything in them, with fine mud, the result of the red marl falling from the cliffs during winter and being washed into the pools. This should make hydroid life impossible, but it does not; they seem to thrive in it (I sometimes think upon it), and cleaning them for the microscope thoroughly disheartens one. Last autumn I was collecting in South Devon, where the cliffs are composed of hard conglomerate, giving fine clean rock-pools. One rock-pool near low-water mark especially attracted my attention. Filled with clear, limpid water, its sides draped with seaweeds, every condition seemed perfect for hydroid life, and yet not a single specimen was found in it. I satisfied myself of this by absolutely cleaning the pool out, examining every piece of seaweed, as I removed it, in a small tank of water, then going carefully over the sides and bottom of the pool with a lens of large diameter. It is little discrepancies like these that both try and puzzle the shore collector.

Hincks has given advice upon shore collecting that cannot well be improved upon, and is as precise as such advice can be. He recommends lying at full length when collecting, and however objectionable this may seem to be in theory, it is

thoroughly sound in practice, and I always adopt it, carrying a mackintosh sheet for the purpose. It should be recollected that a superficial examination of any rock-pool is not sufficient to detect minute species, and even species of considerable size, such as *Plumularia setacea*, often harmonise so well with their surroundings as to be difficult of detection. As far as possible it is best to assume a comfortable position, and then thoroughly examine the basin and the seaweeds it contains, using a lens of about 4 inches diameter when necessary. Many rock-pools have projecting ledges draped with fucus; such are found to be especially prolific if well examined. The fucus should be turned right back, so as to expose the sides it covered and the under surface of the ledge, which are normally in deep shade. Sponges growing underneath may be scraped off and examined for commensal hydroids. If long, dark tunnels exist in the rock, the arm should be pushed up and the upper surface of the rock felt over with the hand for any adherent masses of sponge, etc., which may be broken off and examined. This is a distinctly sporting method, as it gives the crab, when there, a chance to get in first with his pincers. Bring him out and hold him under water in the rock-pool while you go over him carefully with a lens; his carapace will probably recompense you for the pinched finger. Shells, also, should be carefully examined. The only time I ever took *Podocoryne areolata* was upon a shell found lying at the bottom of a funnel-shaped rock-pool, and Professor Allman had the same experience. Many species are so minute as to defy detection by the ordinary methods of shore collecting and are best obtained by taking small tufts of seaweeds and looking over them at home with the compound microscope.

I have remarked previously that collecting is often very remunerative on shores strewn with large fucus-covered boulders. Those who know Llandudno and Criccieth will recognise excellent examples of such shores, and doubtless many similar exist round the coast. The boulders near low-water mark yield the richer harvest, and the underneath is the surface to work. Where two of these huge boulders have fallen close together, so as to form a miniature tunnel, the latter is sure to afford a prolific hunting-ground. My method is to lie on my back and gradually work into the tunnel, carrying a blunt knife and some fair-sized bottles, or jars, of sea-water. The surface of the rock is chipped,

or scraped, where promising growth appears, and the gathering dropped into the bottles, to be examined elsewhere and in a more comfortable position. This is really an excellent method of obtaining material.

Dredging is not likely to be undertaken by the occasional collector unless he is a very enthusiastic one, and if undertaken the individual will probably be in no need of advice from me, as he will know more or less about it. To the beginner I would say, choose a dredge of moderate size and confine dredging operations to moderate depths, *i.e.* up to ten fathoms. If any fishing industry is carried on where the collector happens to be, he may get ample employment from a bucket of trawl refuse obtained from one of the boats; even the rejectamenta of lobster-pots is a good hunting-ground. On an open sandy coast, after a gale or heavy sea, deep-water specimens may be obtained in excellent condition if the jetsam left by a receding tide is carefully looked over. They should be promptly placed in bottles of sea-water, to recover and expand their tentacles, and this process may be aided by vigorously aerating the water by means of a syringe.

Having collected the material, the less eventful work of preparing it for the microscope follows as a matter of course, and I believe I am doing beginners a service in urging upon them the desirability of arranging for this to take place at the earliest possible moment after collecting. Once the hydroids begin to feel the effects of overcrowding and badly aerated water the polyps withdraw into their calycles, and require a large expenditure of time and patience to coax them to expand again. The best results are undoubtedly got when the collector is in a position to go straight from the shore to his microscope and deal with the material collected. The polyps are then vigorous from their normal environment, less intolerant of the narcotising agent, and a considerable quantity of material can be dealt with in a comparatively short time, as there is no tedious waiting for the polyps to expand. My own method is to divide the collection into two lots, separating the Gymnoblastea from the Calyptoblastea, as the former can be best prepared by killing without the intervention of a narcotic. The hydroids are placed in watch-glasses (or better still small Petri dishes) with clean fresh sea-water, and cleansed as far as can be without injuring

the polyps by gently brushing the polypary with a camel's hair brush. They are allowed to recover from the shock, and then a few drops of 1-per-cent. cocain hydrochlorate added to each watch-glass and the glasses set gently aside until all the species have been dealt with. When the polyps are fresh and vigorous narcotisation is not a difficult process, nor one requiring extreme care, but should the hydroids be left twenty-four hours or so before dealing with them the process is likely to be not only tedious but generally unsuccessful. When the polypites are judged to be sufficiently narcotised to permit of killing the tentacles should be pricked with a needle somewhat roughly, to be quite certain that narcotisation is sufficient to prevent retraction of the tentacles. I learnt by experience that even when insensibility was apparently well established, on the application of the killing and fixing agent the polypites would withdraw at least partially, perhaps wholly, into the calycles, so that it is necessary to be quite sure that narcotisation is complete before using the fixing fluid. The killing and fixing agent most convenient is undoubtedly osmic acid, either a plain 1-per-cent. solution or combined with platinum chloride as in Hermann's solution. I have tried many other solutions for this purpose, but found none more suitable. The osmic-acid solution is sprayed over the colony in the watch-glass with a pipette and allowed to act for several minutes, when it is washed away by repeated changes of clean fresh water, allowing the specimens to soak in each wash water for some time. Finally they are given a weak bath of hydrogen peroxide or potassium ferrocyanide, to thoroughly eliminate the acid, and again well washed. This is the procedure for Calyptoblastic hydroids, the Gymnoblastic may have a little more cavalier treatment. If narcotisation is attempted with them it has the effect of causing them to gradually shorten the tentacles, and once that has taken place they never extend them again while under the influence of the narcotic. This being the case the best method is to kill them suddenly with an energetic killing agent while fully expanded. Some retraction of the tentacles may take place in the killing, but to nothing like the extent that would happen if narcotisation were attempted. It is unfortunate that mono-bromide of camphor is insoluble in sea-water, as I am convinced, from the admirable results it gives with Cordylophora and Hydra, that

it would form an excellent narcotiser for this division. Lang's fluid is a good killing agent for the Gymnoblastea, and, of course, assists staining if carmine is used. Picric acid also answers well; and osmic acid or Hermann's solution if the specimens are not too large, otherwise I have found the killing occupy sufficient time to permit of considerable contraction.

Undoubtedly the great difficulty in preparing hydroids for the microscope lies in getting clean mounts—that is, supposing clean mounts are desired—and this difficulty becomes augmented with material from between tide-marks. The polyparies are generally encrusted and overgrown with an olla podrida of marine life, so that the mount really becomes a compound object. To me this is anything but a drawback, providing, of course, that no essential part of the hydroid is masked. On some shores, however, the amount of material collected is out of all proportion to its interest, and it becomes necessary to subject it to a cleansing process. This should be done before narcotising and killing the hydroid, otherwise the tentacles are liable to be injured and entangled. The polyps withdraw into their calycles during the application of the brush, but soon recover from their fright when placed in a glass of clean fresh water and allowed to rest quietly for a time.

If staining and mounting fixed material are deferred until a more convenient time, it has to be stored in some preservative fluid; formalin at once suggests itself, for which reason I wish to utter a word of warning. Formalin is perfectly satisfactory for objects that are to be mounted unstained, as they will eventually find a permanent home in this medium, but personally I have not been successful in staining material that has been stored for some months in a 5-per-cent. solution of formalin. This, of course, may be due to some error peculiar to myself, but I would offer this warning to inexperienced workers. If time and facilities allow I would strongly advise the beginner to stain straight away, and if unable to mount, then store the stained material in 70-per-cent. alcohol. Failing this, I think it preferable to store those hydroids destined for staining in 70-per-cent. alcohol. In storing avoid the error of putting too many into one tube; small tubes with a few in each are very much better than a heterogeneous collection of species in a large tube or bottle.

The microscopist will doubtless have his own pet stain or stains,

and as a good general stain is all that is required for systematic work it does not much matter which is used. I have used principally para-carmine, carmalum and haemalum of Mayer's formulae; the last of which I prefer on account of its better visual properties, also because it stains exceptionally well objects that have been fixed with osmic acid. I may here mention that haematoxylin has been regarded by some workers as a fugitive stain; why, I am unable to discover. I attempted to bleach some slides that had been over-stained by exposing them for some months in a window with a south aspect, and at the end of that time withdrew them as hopelessly permanent. They should have faded, according to all the authorities, but much to my disgust they did not.

For unstained objects I use excavated slips, and a $2\frac{1}{2}$-per-cent. solution of formalin. A ring of old, fairly thick gold size is run round the edge of the hollow and allowed to become nearly dry, at least dry enough to retain the impression of a scratch made with a needle. The selected portion of the hydroid colony is placed in the cell, and $2\frac{1}{2}$-per-cent. formalin solution added until a full cell with a convex surface to the fluid is obtained. The cover-glass is then placed in position, expelling the superfluous formalin. Under a mounting microscope, with a strong blunt needle, the cover-glass is pressed into intimate contact with the ring of gold size, until it can be seen that no lacunae exist between it and the cover-glass. The extraneous formalin is now removed and the slide allowed to dry, when several rings of gold size may be applied. Slides so prepared have attained the comparative antiquity of sixteen or eighteen years without showing any deterioration.

As this paper has been prepared with the object of placing practical information before those desirous of devoting some attention to our hydroid fauna, it may not be considered alien to the subject if I refer briefly to various localities of which I have personal knowledge, from collecting more or less frequently in them; merely premising that my acquaintance with them as collecting-grounds has been more by accident than design, and I have no wish to suggest that they are any more desirable from the collector's point of view than numbers of others unknown to me. In North Wales my collecting-stations have been Llandudno, Menai Straits, Criccieth and Barmouth. Llandudno and Criccieth are excellent grounds. The rocks at Llandudno under the Great

Orme afford plenty of work at low tide, but rock-pools are practically non-existent; I have taken many good northern species from the under-sides of the boulders strewn about. Criccieth is a capital ground; the rocks on the shore at the foot of the Castle Hill repay the most ample attention, yielding many and good species. A short distance from Criccieth are the Black Rock caves, which are really a paradise for the shore collector, but are only accessible at low tide. The Menai Straits, also, have good collecting-spots on the rocks at the Suspension and Tubular bridges, but the drawback to work thereabouts is the swiftness of the tide, which makes boating difficult and risky unless accompanied by a local boatman. Pennington collected many species between the two bridges. Staithes, in Yorkshire, has a good shore for collecting, as the rock-pools are ample. Coming now to Devonshire, with whose shores I have intimate acquaintance, we reach ground made classic by the labours of Gosse, Hincks, Allman, Kingsley, Montagu and many others. Ilfracombe, in North Devon, has the advantage of clear rock-pools, in places an almost vertical rise and fall of tide, and excellent boating and dredging. As it has received its meed of praise at the hands of such authorities as Hincks and Gosse, not to mention Lewes, it may be considered sufficiently hall-marked. Torquay, Gosse's home and hunting-ground *par excellence*, is indubitably an ideal district; I know no better. The collecting at the Corbon's Head alone will occupy a long holiday, and the coast under Livermead, Kingsley's one-time residence, is honeycombed with charming rock-pools full of hydroid life. At Brixham one gets in touch with a trawling district, and plenty of chances occur of going over trawl refuse. In East Devon, from Exmouth to Sidmouth, the naturalist has to set a watch on his lips, for the combination of excellent rock-pools and cliffs of Keuper marl is more than the average shore collector can bear unmurmuringly. At the same time, the fauna of these rock-pools is both luxuriant and diversified; and one has to remember that it was principally in East Devon that Hincks collected both hydroids and Polyzoa.

I would conclude with an apology for the extremely elementary nature of this paper. It is a mere account of personal methods, offered to the inexperienced in the hope of smoothing away some of those preliminary difficulties that appear to be "commensal" with the early days of all new subjects.

Notes on Some Species of Hydroida, principally intended for Purposes of Identification.

Clava multicornis.

The polypites in this species are scattered, not grouped as in the next.

Clava squamata.

Polypites in groups, clustered, gonophores in dense clusters at base of tentacles.

Clava cornea.

Clusters of polypites much smaller than in *C. squamata*, gonophores smaller and less densely clustered. The two species are closely allied, and Dr. T. S. Wright considered *cornea* a variety of *squamata*.

Podocoryne areolata.

Apparently a rare species, as Hincks only records it from three localities. It is easily distinguished by the sessile gonophores being borne on the chitinous expansion of the stolon.

Coryne vaginata.

The common species of the south coast, and may be recognised principally by the cup-like membranous expansion of the polypary. It is essentially a rock-pool species.

Coryne pusilla.

In this species the tentacles are "more truly whorled than in any other form of Coryne" (T. H.). The polypites are linear in shape, and "of about equal size from one extremity to the other" (T. H.). The only specimen I have ever had was found in some material sent from Marazion.

Eudendrium ramosum.

The height given for this species by Hincks is "about 6 inches," but it appears to become dwarfed as it nears a littoral habitat.

Eudendrium insigne.

In the absence of gonophores the specific name can only be given with considerable hesitation. Hincks states its habitat

to be between tide marks on the south coast, and mentions a circular groove near the base of the body as a means of identification.

Perigonimus sessilis.

The only species with ringed coenosarc. The polyp not dilated underneath the tentacles.

Bougainvillea muscus.

Allman distinguishes this species by its small habit and the fact that its stems consist of a single tube, instead of being composed of several tubes coalesced into one. The records for this species seem to be very scanty.

Clytia Johnstoni.

The pedicel in this species is usually ringed at the top and at the bottom, being smooth in the middle portion. Some specimens are, however, more or less ringed throughout.

Obelia geniculata.

This species is readily distinguished by the projections supporting the ringed pedicels bearing the hydrotheca.

Campanularia neglecta.

The margin of the calycle in this species is crenulate. This can only be seen with difficulty, as it is so readily damaged.

Halecium Beanii.

It may be easily identified when bearing female capsules by their distinctive shape and the short tubular orifice in the middle of the capsule.

Sertularia filicula.

This hydroid varies in the position of the calycles on the stem, some being placed oppositely, and some more or less alternately. It may be distinguished by the single erect calycle in the axils of the branches. It is a deep-water species (20 fathoms), and more especially a northern species. Hincks never met with it in Devon or Cornwall, so its occurrence in rock-pools at Sidmouth is somewhat noteworthy.

Plumularia pinnata.

The Plumulariidae are somewhat difficult for the beginner to separate, owing to the superficial resemblance of one species with another. The most trustworthy means of separating the species is by a careful observance of the nematophores and distances of the calycles. In *P. pinnata* the nematophores are very minute, and lack the pronounced calycle present in other species, and are one below each hydrotheca. The gonothecae also, when present, help materially in distinguishing the various species. In the present species they are ovate, with spinous projections on the top.

Plumularia setacea.

It somewhat resembles the former species, but the nematophores are very different, being of superior size and differing in number. The gonothecae are quite different, being flask-shaped; their axillary position also is an aid to diagnosis.

Plumularia echinulata.

In this species the pinnae have an unmistakable arched form which does not occur in the others. The nematophores are smaller than in *P. setacea*, and one nearly always occurs in the axils of the pinnae. The gonothecae, however, when present readily determine the species.

Plumularia similis.

This appears to be very near the former species (*P. echinulata*), but the gonothecae are totally dissimilar, being without the spinous projections.

Plumularia halecoides.

A minute species, and easily overlooked. The polypites have been compared to an hour-glass in shape. The gonothecae are transversely ribbed. Nematophores very minute and difficult to detect.

[The above notes are intended for use with a series of slides presented to the Cabinet by Mr. G. T. Harris.]

THE MINUTE STRUCTURE OF *COSCINODISCUS ASTEROMPHALUS* AND OF THE TWO SPECIES OF PLEUROSIGMA, *P. ANGULATUM* AND *P. BALTICUM*.

By T. A. O'Donohoe.

(*Read May 28th*, 1913.)

Plate 14.

In preparing this paper it was, at first, my intention to refer in no way to the work of others, of which, in fact, I had very little knowledge. It has, however, been pointed out to me that it is desirable to mention previous researches, in order to enable the reader to compare these more easily with my own. Happily Mr. E. M. Nelson gives a brief summary of his work on the valve of Pleurosigma in a note read at the Club on January 28th, 1913 (*Journ. Q. M. C.*, vol. xii., p. 98). This note is therefore easily accessible to all my readers, and any further reference to it by me would be unnecessary. I regret I cannot so easily dispose of the observations of Mr. T. F. Smith, who has for many years devoted much time and thought to the structure of diatoms, and who has so recently as August 1911 and October 1912 contributed to *Knowledge* two papers on this much-discussed subject, entitled "The True Structure of the Diatom Valve." These papers contain very many photo-micrographs, of which several are excellent. I very much regret, however, that I cannot agree with what I must call his heterodox views. In his own words, "The points desired to be driven home in the present article are that diatom structure consists of neither beads nor perforations as commonly understood" (page 291).

Speaking of *Pleurosigma formosum*, he says: "It appears to consist of a series of chains, as it were, formed of short bars or fibrils of silex, arranged lengthways on the valve. They run in pairs, parallel, each pair having larger and narrower interspaces between them in regular succession, and so placed that the larger interspaces are set obliquely to the corresponding interspaces between the other pairs both above and below." A few lines farther on he tells us that "his theory is this, that what we see in the Pleurosigma valve when sound is not the structure at all, but simply a collection of focal images thrown from the other

layer upon the one nearest the eye, just as a picture is thrown from the optical lantern upon a canvas screen. The fibrils or grating is the real structure, of which the texture is concealed, even as that of the canvas screen is concealed by the picture." So much for this new theory. We can consider only a few of its points. The figures given on page 289 are, we are told, photomicrographs of the two separated membranes of a valve of *Pleurosigma angulatum*. If two really good photographs were taken of these two membranes at about 4,000 diameters, they would, in my opinion, make an end of Mr. Smith's theory, but instead of giving his readers two such images, which would be extremely interesting and valuable, he gives them a great number of *outersides* and *innersides* which, he tells us, do not show the structure at all, and are therefore of very little value. Indeed, I may say for myself that I attach little or no value to interpretations of fine diatomic structure other than those of thoroughly separated single membranes. Of these only can we speak with a fair degree of certainty.

Turning now to page 331, we find that Mr. Smith says: "Fig. 14 is from an innerside of another valve (of *P. formosum*), the first ever seen and taken, showing the fracture through undoubted perforations," and Mr. Nelson, being called to his aid, testifies that "Mr. Smith has found this fracture, had shown it to him, and that at any rate the fracture did run through the holes." So, too, Mr. Smith cites the testimony of Dr. Dallinger, who says: "In Plate I. fig. 1 (Carpenter on the Microscope) we have a photograph of his showing the inside of a valve of *Pleurosigma angulatum* magnified 1,750 diameters, exhibiting the "postage-stamp fracture." The postage-stamp fracture is, as everybody knows, a fracture through the holes, so that we have these two great authorities testifying to the fact that these photographs of Mr. Smith show fractures through *holes*, or, as Mr. Smith calls them, *undoubted perforations*. His theory being that there are neither holes nor beads in the valve of a Pleurosigma, does he now repudiate these photographs and these testimonies? He speaks of his fibrils forming interspaces, chains and gratings, and it would be interesting to have his definitions of these terms. Can there be chains or gratings without intervening spaces, *i.e.* holes or perforations?

Fig. 18, page 333, "The innerside of *Pleurosigma angulatum* $\times$ 3,770," by no means a sharp image, shows, nevertheless, holes galore to any one who is not blind or unwilling to see them.

Mr. Smith's second paper (October 1912) I cannot touch: the exigencies of space forbid.

I am indebted to two members of the Club for the loan of two slides—realgar mounts—which have enabled me to study the minute structure of *Pleurosigma angulatum* and *Pleurosigma balticum*. Having taken several photographs from a slide lent me by my friend Mr. Bruce Capell, I showed some of them to our Secretary and Editor, and the latter informed me that Mr. Nelson was engaged more or less on the same subject, and suggested that I should send him copies of my photographs. This suggestion I fell in with the more readily inasmuch as it would give me the benefit of any adverse criticism which Mr. Nelson might feel himself called upon to make. To elicit this I wrote on the back of each a brief interpretation of the structure, and in one case in which I was much puzzled I placed a note of interrogation. With his usual kindness and urbanity, Mr. Nelson gave the desired information, but instead of adverse criticism he sent me two slides of great historic as well as intrinsic value. From these I have been enabled to make some photographs which confirm the results already obtained from the slide belonging to Mr. Bruce Capell.

Coming now to my immediate subject, my readers are, no doubt, aware that Dr. Van Heurck tells us that a diatom valve consists of two membranes and of an intermediate layer which he calls a septum, and that it is this latter layer which contains the cavities or perforations. In my opinion this definition connotes at once too much and too little: too much by giving the valve three layers, and too little by confining the cavities to the septum only. In the three valves which we are about to consider, I find only two layers or membranes, each of which has its own perforations. We will, in the first place, consider the structure of *Coscinodiscus asteromphalus*. The photographs are taken from some of my own mounts in styrax. Of course I am aware that this valve was very ably and fully treated recently elsewhere by Dr. Butcher (*Journ. R. M. S.* 1911, p. 722), but my chief object in bringing it before you now is to determine, if we can, which is the correct image, the black dot or the white dot. [Here Mr. O'Donohoe illustrated his remarks by photographs projected on the screen.] The black- and white-dot images now thrown on the screen have been taken direct at a magnification of 4,000 diameters, and to my mind it seems perfectly obvious that two images so utterly unlike one another cannot both be correct

representations of the same structure. The next two slides show the inner membrane projecting beyond the outer one, and on examining the edge of the fracture it becomes at once evident that what is called the eye-spot is a comparatively large perforation. This membrane also shows considerable thickness. I have been able to find a small fragment in which the outer membrane projects a little beyond the inner layer. This is seen by the fact that the silex of the projecting part appears white. It should now be noted that this white silex is sharply defined at the edge, that this edge shows hardly any thickness, and that the perforations are represented by black dots. The next image has been obtained by making no other alteration than that of raising the objective until the white dots appeared. On examining this image we find the white silex has become black, and the edge of the fracture which was so well defined in the black-dot picture is now so blurred and fogged as to have become invisible. We have next two fragments of *Pleurosigma angulatum* in juxtaposition, showing respectively the black and white dots. The black dot image gives the "postage-stamp" fracture well defined in white silex, whereas the broken edge in the other fragment is black, out of focus and blurred. We are therefore justified, I think, in relegating the white-dot images of diatom structure to the abode of Mr. Nelson's ghosts. Here, methinks, I hear the tyro in microscopy cry out, "If that be so, why do we meet with so many white-dot images in the books which are written for our guidance?" I prefer to let the writers of these books answer for themselves. Mr. Pringle, in *Practical Photomicrography*, 1890, page 173, writes: "In spite of all these details, *A. pellucida* is child's play to photograph in comparison with such tests as *Pleurosigma angulatum*, *Surirella gemma* and *Navicula rhomboides* by axial light and to show 'black dots. *Pleurosigma angulatum* in white areoles, or *Navicula rhomboides* in squares, with a special disc in the condenser, is infinitely easier than the same in black dots."

Let us turn now to Plates III. and IV. of Dr. Spitta's *Photomicrography* (1899). What do we find? White-dot images of all his diatomic tests. Not one black-dot image! He has, no doubt, some good reason for this, and turning to page 138 we find it. Writing about the photography of *Pleurosigma angulatum*, Dr. Spitta says: "It has two principal planes of focus, and much difference of opinion exists as to which is the correct one. The last picture taken by Dr. Van Heurck with

the new Zeiss N.A. 1·6 objective, and the attendant paraphernalia, seems to show that after all the black dot is more correct than the white one. As before stated, the white one is the easiest to photograph, for the black dot seems never to be sufficiently defined to look as sharp as we should like it."

For the sake of the aforesaid tyro I will here quote a little advice which Mr. Nelson gave me eight years ago (I began photomicrography very late in life) on the white dot. Among several black-dot photographs which I sent him, and which he was kind enough to praise, there was a white-dot *Isthmia nervosa* of which he said: "I think the Isthmia would be better with black-dot focus; this white-dot focus is an out-of-focus ghost. It is much easier to get than a correct picture, and on that account it seems to be a favourite with some photographers; but any one really interested in the work should aim at something higher. Of course, with very fine structures, a white dot is all that can be obtained with our present lenses." I thought then, and still think, that this was the kind of mentor who would always command and receive the highest respect.

We come now to *Pleurosigma angulatum*, of which a black-dot image × 3,700 is thrown on the screen. The next picture on the screen shows a fractured valve which has been denuded of a part of its outer membrane. The next image shows this outer membrane × 2,000 broken up into fragments so minute that the particles of silex have in some instances only one, two, three or four holes shown as black round dots; this outer membrane is so thin that the silex is almost invisible, and in this respect differs very much from the inner membrane, whose image × 2,000 is now thrown on the screen. I do not, however, discern any difference between the holes in the two membranes.

Finally, we have to consider the structure of *Pleurosigma balticum*. This, because of its convexity and thickness, is difficult to photograph, and yet more difficult to understand. I am illustrating its structure by showing you fifteen different photographs, each of which I must describe very briefly; but before doing so, let me define the word "fibril": a fine filament of silex which contains holes in a row like a string of beads; it may be long or short. This definition differs altogether from that which Mr. T. F. Smith gives to the same word.

The first slide shows the ordinary valve with Van Heurck's canaliculi × 1,500.

The second slide shows the round black dots of the inner membrane near the nodule, where the outer membrane has been rubbed off (Pl. 14, fig. 1). The third slide shows an impression of the greater part of a valve caused by the adhesion of the outer membrane to the slip.

The fourth slide shows a similar adhesion to the cover-glass, as well as the valve from which the outer membrane was torn. The fifth shows the same × 1,000.

The sixth slide shows fine hair-like bent fibrils breaking away from the valve.

The seventh shows a part of the same valve × 2,000, on which four fibrils of the inner membrane are visible.

The eighth is an image which puzzled me, and Mr. Nelson kindly explained it thus: "This shows an upper bar crossing a hole. It also shows the transverse girder work wonderfully clearly" (Pl. 14, fig. 2). The ninth slide shows the structure of the inner membrane to be similar to the last, but this and the three next following photographs were taken from Mr. Nelson's slide.

The tenth shows the outer membrane breaking up into fibrils, and sometimes even into isolated dots (Pl. 14, fig. 3).

The eleventh and twelfth show continuations of the tenth. The thirteenth shows the structure of the fibrils very well (Pl. 14, fig. 4). The fourteenth and fifteenth show the kind of structure which is incorrectly taken for squares, but a glance at one of the single fibrils causes the optical illusion to vanish.

In *Pleurosigma balticum* the fibrils run parallel with the raphe, whereas in *Pleurosigma angulatum* they seem to run obliquely to the raphe, and this, it seems to me, is the chief difference in the minute structure of the two valves.

Description of Plate 14.

Fig. 1. *P. balticum*, × 1,750. Showing the structure of the inner membrane when the outer has been rubbed off.

„ 2. *P. balticum*, × 2,000. Inner membrane, showing the holes crossed by very fine bars of silex.

„ 3. *P. balticum*, × 2,000. Fibrils, photographed from Mr. Nelson's slide.

„ 4. *P. balticum*, × 1,250. Fibrils.

Fig. 1.

Fig. 3.

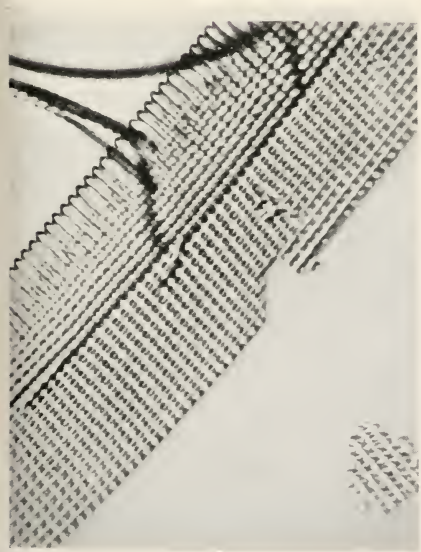


Fig. 2.

Fig. 4.

Photomicrogr. T. A. O'D.

Structure of *Pleurosigma balticum*.

LAGENAE OF THE SOUTH-WEST PACIFIC OCEAN.

(SUPPLEMENTARY PAPER.)

By Henry Sidebottom.

(*Read June 24th*, 1913.)

Plates 15-18.

INTRODUCTION.

The Lagenae dealt with in this supplementary paper were arranged by the late Mr. Thornhill on nine slides, each of which is divided into one hundred squares. Nearly every square is occupied, with the exception of some on the last slide. The number of specimens exceeds twelve thousand. In the material for my first paper the number of specimens of Lagenae exceeded six thousand, thus making a grand total of over eighteen thousand. For reasons stated in my former Introduction, it has not always been possible to give the locality at which specimens were found.

The series dealt with now is on three sets of slides, Nos. **1–4** A being *Penguin* gatherings, Nos. **1–3** B *Penguin* and *Dart* gatherings combined and Nos. **1, 2** C those on which Mr. Thornhill had just begun to bring together specimens arranged according to a system he had hoped to carry out.

The specimens of Lagenae on the three sets of slides were not arranged in sequence with each other, so that the work has proved more laborious than that of my first report.

The division of the keel, which occurs in a good many tests and in more than one species, adds to the difficulty of identification, and it is easy to be misled by it. The same may be said of some of the markings on the faces of the test, which have hitherto been considered as specific characters.

Again I must acknowledge the kindness of Mr. Millett, whose advice I have always found most valuable and freely given. My thanks are due to Mr. Wright, of Belfast, to Prof. Hickson, of the University of Manchester, for kind assistance, and also to Mr. Earland for bringing these papers before the Quekett Microscopical Club and examining specimens for me in order to

find out the nature of certain markings. Lastly, as regards the text, I wish to acknowledge my indebtedness to my wife for her assistance in rendering my descriptions more concise.

H.M.S. "Penguin." S.W. Pacific. 1897.

No.	Station.	Lat. & Long.	Fms.	No.	Station.	Lat. & Long.	Fms.
1.	939.	18·29′ S. 178·38′ E.	1,122.	12.	959.	31·39′ S. 176·49′ E.	2,210.
2.	940.	18·57′ S. 179·04′ E.	1,092.	13.	961.	33·00′ S. 176·16′ E.	2,086.
3.	941.	18·43′ S. 178·51′ E.	1,360.	14.	964.	34·52′ S. 175·34′ E.	917.
4.	943.	19·21′ S. 179·30′ E.	1,420.	15.	974.	35·01′ S. 171·37′ E.	796.
5.	945.	21·47′ S. 179·25′ E.	2,043.	16.	975.	35·23′ S. 170·34′ E.	994.
6.	947.	22·49′ S. 179·20′ E.	1,948.	17.	976.	36·09′ S. 169·20′ E.	1,298.
7.	949.	23·44′ S. 179·09′ E.	1,903.	18.	986.	36·30′ S. 168·11′ E.	1,207.
8.	952.	25·52′ S. 178·47′ E.	2,183.	19.	987.	37·10′ S. 166·30′ E.	822.
9.	954.	26·57′ S. 178·35′ E.	2,318.	20.	996.	37·47′ S. 164·40′ E.	735.
10.	955.	27·46′ S. 178·29′ E.	1,803.	21.	998.	38·24′ S. 163·15′ E.	2,182.
11.	956.	29·17′ S. 177·17′ E.	2,050.	22.	1,003.	43·05′ S. 148·39′ E.	1,611.

H.M.S. "Penguin." S.W. Pacific. 1898.

No.	Station.	Lat. & Long.	Fms.	No.	Station.	Lat. & Long.	Fms.
23.	3.	33·53′ S. 157·29′ E.	2,578.	25.	35.	34·19′ S. 168·6′ E.	828.
	4.	33·50′ S. 158·47′ E.	2,338.		41.	34·20′ S. 168·28′ E.	1,191.
24.	5.	33·48′ S. 160·2′ E.	1,190.		44.	34·22′ S. 170·19′ E.	979.
	7.	33·56′ S. 161·13′ E.	988.	26.	75.	36·21′ S. 176·44′ E.	832.
	12.	33·56′ 7″ S. 162·33′ E.	498.		79.	36·3′ S. 178·55′ E.	1,389.
	18.	33 56′ 6″ S. 163 20′ E.	575.	27.	83.	34·33′ S. 178·15′ W.	4,278.
	21.	33·57′ S. 163·56′ E.	603.	28.	85.	32·56′ S. 176·49′ W.	3,360.
	24.	33·58′ S. 164·37′ E.	1,073.		86.	32·16′ S. 175·54′ W.	3,220.
	25.	33·58′ 5″ S. 164·55′ E.	1,653.		87.	31·28′ S. 171·5′ W.	3,100.
	27.	34·0′ 6″ S. 165·37′ E.	1,676.				

No.	Station.	Lat. & Long.	Fms.
29.	93.	26·38′ S. 174·17′ W.	2,420.
30.	90.	29·17′ S. 175·11′ W.	3,105.
	94.	25·53′ S. 174·6′ W.	2,775.
	95.	23·24′ S. 173·40′ W.	3,205.
	96.	22·14′ S. 173·29′ W.	3,420.
31.	98.	21·8′ S. 174·7′ W.	2,115.
32.	143.	23·15′ S. 175·32′ E.	2,351.
33.	148.	26·1′ S. 172·56′ E.	2,428.
	149.	26·38′ S. 172·26′ E.	2,070.
	151.	27·55′ S. 171·22′ E.	1,632.
34.	156.	29·35′ S. 168·51′ E.	1,269.
	157.	29·42′ S. 168·51′ E.	1,446.
	167.	30·29′ S. 166·16′ E.	1,819.
35.	169.	30·57′ S. 160·52′ E.	1,557.
36.	172.	31·18′ S. 163·46′ E.	1,010.

H.M.S. "Penguin." S.W. Pacific.

No.	Station.	Lat. & Long.	Fms.
37.	140.	10·57′ S. 162·21′ E.	508.
38.	70.	23·17′ S. 154·33′ E.	470.
39.	181.	11·42′ S. 175·51′ W.	2,335.
	182.	11·09′ S. 175·36′ W.	1,992.
	188.	9·41′ S. 174·37′ W.	2,290.
	191.	8·57′ S. 174·03′ W.	2,606.
	192.	8·36′ S. 173·51′ W.	2,712.
40.	393.	3·51′ N. 164·13′ W.	2,330.
	429.	4·55′ N. 160·54′ W.	1,701.
	480.	5·10′ N. 160·15′ W.	2,033.
40.	482.	6·15′ N. 160·36′ W.	1,861.
	487.	7·25′ N. 160·59′ W.	2,501.
	488.	7·47′ N. 160·45′ W.	2,573.
	498.	8·47′ N. 159·45′ W.	2,588.
41.	499.	9·04′ N. 159·32′ W.	2,579.
	502.	9·43′ N. 159·07′ W.	2,758.
	503.	10·04′ N. 158·53′ W.	2,800.
	505.	10·43′ N. 158·30′ W.	2,938.
	506.	11·01′ N. 158·21′ W.	2,863.

H.M.S. "Dart."

No.	Station.	Lat. & Long.	Fms.
42.	No date.	24·15′ S. 153·15′ E.	328.
		24·34′ S. 153·32′ E.	478.
		24·36′ S. 153·32′ E.	392.
43.	19. (14.5.97.)	29·22′ S. 153·51′ E.	465.
44.	(16.1.97.)	38·14′ S. 149·54′ E.	481.

Family LAGENIDAE.

Sub-family **Lageninae.**

Lagena Walker and Boys.

Lagena globosa Montagu sp. (Pl. 15, figs. 1–3).

Serpula (*Lagena*) *laevis globosa* Walker and Boys, 1784, *Test. Min.*, p. 3, pl. 1, fig. 8.

Vermiculum globosum Montagu, 1803, *Test. Brit.*, p. 523.

Very numerous and of varying size and shape. The orifice and internal tube are subject to great variation.—*Locality:* Many stations.

Pl. 15, fig. 1. The orifice is small and somewhat hooded, and the test often inclined to be apiculate.—*Locality:* Many stations. Rare.

Pl. 15, fig. 2. An elongate variety.—*Locality:* Uncertain. Only one found.

Pl. 15, fig. 3. An interesting variation, the body of the test being partly clear and partly opaque. The curiously produced, flattened mouth, which appears to be divided or pinched in at the centre, points to its being allied to the one figured ✢ Pl. 14, fig. 2.* The entosolenian tube is absent.—†*Locality:* Nos. **24–26, 34, 38, 42, 44.**

✢ Pl. 14, fig. 2.—*Locality:* Uncertain.

✢ Pl. 14, fig. 4. The slightly elongated form predominates.—*Locality:* Many stations, including Nos. **6, 8**; after No. **22** only at one or two stations.

✢ Pl. 14, fig. 5. This compressed variety of the above is found sparingly at a few stations, but tests that are much more compressed, and pointed towards the aperture, are frequent.

Lagena globosa Montagu sp. single and bilocular form.

Lagena globosa Montagu sp. single and bilocular form, Sidebottom, 1912, *Journ. Q. M. C.*, p. 380, pl. 14, figs. 7, 8, 9.

Locality: Many stations up to No. **19**, also at Nos. **33, 43, 44.**

* The "✢" denotes that the reference is to "Lagenae of the South-West Pacific Ocean" (*Journal Quekett Microscopical Club*, 1912, ser. 2, vol. xi., pp. 375–434, pls. 14–21).

† The numbers throughout this paper refer to my charts on pp. 162, 163, where will be found the official numbers of the stations, with other particulars.

Lagena globosa Montagu sp. var. *maculata* Sidebottom.

Lagena globosa Montagu sp. var. *maculata*, Sidebottom, 1912, *Journ. Q. M. C.* p. 380, pl. 14, figs. 10, 11.

Locality: Nos. **5–9**.

Lagena globosa Montagu sp. var. *emaciata* Reuss.

Lagena emaciata Reuss, 1862 (1863), p. 319, pl. 1, fig. 9.
Lagena globosa Montagu sp. var. *emaciata* (Reuss) Sidebottom, 1912, *Journ. Q. M. C.* p. 381, pl. 14, figs. 13–15.

Locality: Present at numerous stations throughout the series.

Lagena apiculata Reuss sp. (Pl. 15, fig. 4).

Oolina apiculata Reuss, 1851, p. 22, pl. 1, fig. 1.
Lagena apiculata Reuss, 1862 (1863), p. 318, pl. 1, figs. 1, 4–8, 10, 11.

Pl. 15, fig. 4.—A large, solitary specimen.—*Locality:* No. **15**.

÷Pl. 14, fig. 16. Always rare.—*Locality:* At Nos. **24**, **43**, and a few other stations.

÷Pl. 14, figs. 17, 18. Found at many stations.—*Locality:* Chiefly at Nos. **2**, **24**, **42**, **44**.

÷Pl. 14, figs. 19, 20. The tube in this variation is very delicate, and often lies broken inside the test.—*Locality:* Occurs at very many stations.

Lagena apiculata Reuss sp. var. *punctulata* Sidebottom.

Lagena apiculata Reuss sp. var. *punctulata* Sidebottom, 1912, *Journ. Q. M. C.*, p. 382, pl. 14, figs. 21–23.

Locality: Nos. **3**, **5–11**, **41**, **43**.

Lagena longispina Brady (Pl. 15, figs. 5, 6).

Lagena longispina Brady, 1881, *Quart. Journ. Micro. Sci.*, vol. xxi., N.S., p. 61.
Lagena longispina Brady, 1884, p. 454, pl. 56, figs. 33, 36; pl. 59, figs. 13, 14.

As Brady states in the *Challenger* Report, this is simply a variety of *L. globosa*. It is not unusual for *L. globosa* to have the base of the test roughened or finely spinous. The larger of

the two specimens figured is so opaque that it is impossible to say whether the entosolenian tube is present.—*Locality:* Nos. **5, 7, 9, 39–41, 44.**

Lagena ovum Ehrenberg sp.

Miliola ovum Ehrenberg, 1843, p. 166;—1854, pl. 23, fig. 2; pl. 27, fig. 1; pl. 29, fig. 45.

Locality: This unsatisfactory form occurs at many stations, but is always rare. See remarks †p. 382.

Lagena botelliformis Brady (Pl. 15, figs. 7, 8).

Lagena botelliformis Brady, 1884, p. 454, pl. 56, fig. 6.

Pl. 15, fig. 7. Only two specimens found. The orifice is phialine, and there is a short internal tube.—*Locality:* No. **44.**

Pl. 15, fig. 8. This is a very fine example in the apiculate condition. See also †Pl. 14, fig. 24.—*Locality:* No. **12.**

†Pl. 14, figs. 24, 25.—*Locality:* Many stations.

†Pl. 14, figs. 26–28.—*Locality:* Stations uncertain.

Lagena laevis Montagu sp. (Pl. 15, figs. 9, 10).

Serpula (*Lagena*) *laevis ovalis* Walker and Boys, 1784, p. 3, pl. 1, fig. 9.

Lagena laevis (Walker and Jacob) Williamson, 1848, p. 12, pl. 1, figs. 1, 2.

L. laevis occurs frequently in these gatherings, and the form of the test, the decoration of the neck and the position of the internal tube varies. Some are apiculate. In a few instances there is an entosolenian tube situated at the base.—*Locality:* Many stations.

Pl. 15, fig. 9. The tests are semi-opaque, the short neck is decorated and the internal tube straight. In several instances fine spines project at the base.—*Locality:* Nos. **1, 2, 3,** and one or two others.

Pl. 15, fig. 10. This appears to be a smaller variety of the above. The tests are too opaque for me to make out whether the entosolenian tube is present. Some are apiculate and may be *L. laevis* var. *distoma* Silvestri.—*Locality:* At a good many stations throughout the series.

Lagena laevis Montagu sp. var. *distoma* Silvestri.

Lagena laevis (Montagu) Silvestri, 1900, p. 244, pl. 6, figs. 74, 75.

Examples are rare, but they occur at a fair number of stations. —*Locality :* Chiefly at Nos. **1, 6, 11, 15, 17, 22, 42–44.**

Lagena gracillima Seguenza sp.

Amphorina gracilis Costa, 1856, p. 121, p. 11, fig. 11.
Amphorina gracillima Seguenza, 1862, p. 51, pl. 1, fig. 37.

Eight specimens occur which are all curved.—*Locality :* No. **44.**

Besides these specimens, only two or three others were found.— *Locality :* Uncertain.

Lagena elongata Ehrenberg sp.

Miliola elongata Ehrenberg, 1854, pl. 25, 1A, fig. 1.

I do not think these can be separated from *L. gracillima* Seguenza sp., as they appear to pass insensibly from one form to the other. Seven specimens occur, also two or three doubtful examples.—*Locality :* Six at No. **43**, and one at No. **2.**

Lagena aspera Reuss (Pl. 15, figs. 11–13).

Lagena aspera Reuss, 1861, p. 305, pl. 1, fig. 5.

Pl. 15, fig. 11. This is in good condition, except that the neck is broken. The protuberances, which are arranged in lines, are, I think, tubular.—*Locality :* No. **17.**

On another square are two smaller specimens, with very small protuberances ; these also have the neck fractured. They appear to be a weak form of the above.—*Locality :* Uncertain.

Pl. 15, fig. 12. Two specimens only occur ; the one figured is in a very opaque condition, the other is clear but much smaller.— *Locality :* Nos. **1, 22.**

Pl. 15, fig. 13. Three specimens found, the neck being bent to one side in each case. It is not unlikely that future investigation will reveal a connection between these forms and *L. striatopunctata.* —Locality : No. **43.**

There are also two oval tests, which have the protuberances, and the lines in which they are arranged, farther apart. The protuberances are very minute.—*Locality :* No. **10.**

Lagena rudis Reuss (Pl. 15, fig. 14).

Lagena rudis Reuss, 1862 (1863), vol. 46, p. 336, pl. 6, fig. 82.

A single example. The test is opaque and of a faint silvery-yellow colour.—*Locality :* No. **24**.

Lagena ampulla-distoma Rymer Jones.

Lagena vulgaris var. *ampulla-distoma* Rymer Jones, 1872, p. 63, pl. 19, fig. 52. See also + p. 384.

Locality : Nos. **1, 2, 3, 8, 19, 22, 24, 42, 43.**

Mr. Millett, 1901, p. 6, mentions two other localities for this species, besides the Malay Archipelago; it may therefore be worth while to state that I have since recorded it from the coast of Delos and Palermo.

Lagena hispida Reuss (Pl. 15, fig. 15).

Sphaerulae hispidae Soldani, 1798, p. 53, pl. 17, v, x.
Lagena hispida Reuss, 1858, p. 434.
Lagena hispida Reuss, 1862 (1863), p. 335, pl. 6, figs. 77–79.

In one form or another this is found at nearly all the stations. There is great variation in size, and shape of the tests, and many of the small ones have a long entosolenian tube at the opposite end from the neck, so that it is difficult in some cases to say which is the right end up. If turned one way, they might be treated as apiculate forms.

Pl. 15, fig. 15. The orifice is circular and sunk in a depression. The oral end of the test is surrounded by a series of short spines. A solitary example. *Locality :* No. **24**.

+ Pl. 15, fig. 1. Ten specimens occur.—*Locality :* Nos. **5, 6, 8,** and a single example at either Nos. **41** or **42**.

Lagena hispida Reuss, compressed form.

+ Pl. 15, fig. 2.—*Locality :* Nos. **1–3, 5–7, 10, 24, 33, 34, 36, 38–40, 42.**

Lagena hispida Reuss var. *tubulata* Sidebottom (Pl. 15, fig. 16).

Lagena hispida Reuss var. *tubulata* Sidebottom, 1912, *Journ. Q. M. C.*, p. 385, pl. 15, figs. 3–5.

Pl. 15, fig. 16. Nearly all the smaller tests have their necks broken, and a few are very large, as can be judged from the

drawing. The largest specimens have the body much clogged by exogenous shell-growth, or débris, through which small spines often project.—*Locality:* Nos. **17, 19, 24, 25, 35, 36.** Always rare.

÷Pl. 15, fig. 5. This variation, which is much more delicate in every way, is found at many stations.—*Locality:* Nos. **1–11, 24, 25, 33, 35, 36, 39.**

Lagena striata d'Orbigny sp. (Pl. 15, fig. 17).

Oolina striata d'Orbigny, 1839, p. 21, pl. 5, fig. 12.

Many examples at numerous stations. They vary remarkably both in size and decoration. Many are apiculate. ÷See remarks, p. 386.

Pl. 15, fig. 17. In this, the fine costae project at the base. The neck is bent to one side, the body of the test is also slightly curved. On a square by themselves are fifteen tests which have the contour of *L. clavata*, with the point at which the test begins to narrow towards the base sharply angular. Only two are marked on the chart. *Locality:* Nos. **1, 3–5, 7, 8, 12, 17, 21, 24, 34, 39, 40.**

Lagena (*Amphorina*) *Lyellii* Seguenza sp. is found frequently. This form may be treated either as *L. striata*, or *L. sulcata* in an apiculate condition.

÷Pl. 15, fig. 6. Twenty-three specimens are on the slide.—*Locality:* Nos. **2, 3, 4.**

÷Pl. 15, fig. 8. Fourteen fine examples occur, and a number of smaller ones. Taking the whole series into account they pass gradually into *L. Lyellii* Seguenza.—*Locality:* Nos. **2–12, 15, 17, 21, 24, 29, 31, 33, 34, 39, 40, 42, 43.**

÷Pl. 15, fig. 9. Five typical tests are on the slide, but they are mixed with others that are not typical, and so the exact locality cannot be given with certainty. They were found, however, at one or two of the following stations.—*Locality:* Nos. **1, 5, 11, 13.**

On another slide two examples are placed.—*Locality:* Nos. **23, 24.**

Lagena striata d'Orbigny sp. var. *tortilis* Egger.

Lagena tortilis Egger, 1893, p. 329, pl. 10, figs. 61–63.

Two examples only.—*Locality:* Nos. **43, 44.**

Lagena striata d'Orbigny sp. var. *striatotubulata* Sidebottom.

Lagena striata d'Orbigny sp. var. *striatotubulata* Sidebottom, 1912, *Journ. Q. M. C.*, p. 387, pl. 15, figs. 11, 12.

This is well represented. A good many are more or less fractured, otherwise they are clean and fresh-looking.—*Locality :* Nos. **4–12, 23, 24, 29, 33, 34, 39, 40.**

Lagena distoma Parker and Jones.

Lagena laevis var. *striata* Parker and Jones, 1857, p. 278, pl. 11, fig. 24.

There is a single large specimen and it agrees with the *Challenger* figure, pl. 58, fig. 11.—*Locality :* No. **2.**

There are about twelve examples which have their sides slightly curved and parallel as in the type.—*Locality :* Uncertain.

Lagena lineata Williamson sp.

Entosolenia lineata Williamson, 1848, p. 18, pl. 2, fig. 18.

Many examples found.—*Locality :* Nos. **1, 2, 4, 5, 9, 10, 13–15, 17–20, 22, 24, 25, 36, 38, 42–44.**

+ Pl. 15, fig. 15. The variety with the costae curved occurs at many stations.

Non-apiculate forms also are present.

Lagena variata Brady.

Lagena variata Brady, 1881, *Quart. Journ. Micr. Sci.*, vol. 21, N.S., p. 61.

Lagena variata Brady, 1884, p. 461, pl. 61, fig. 1.

Only two typical examples.—*Locality :* Uncertain.

+ Pl. 15, fig. 13. The neck of the test is in many cases not so long as in the figure referred to.—*Locality :* Nos. **14, 15, 17, 19, 22, 24, 25, 44.**

Lagena costata Williamson sp. (Pl. 15, figs. 18, 19).

Entosolenia costata Williamson, 1858, p. 9, pl. 1, fig. 18.

Occurs frequently, typical and otherwise, sometimes apiculate. Pl. 15, fig. 18. This appears to be an elongate form with from

eight to ten costae. Entosolenian tube straight.—*Locality:* Uncertain; probably No. **22** and a few other stations.

Pl. 15, fig. 19. These appear to be the same, but they have only six costae, and occur more frequently.—Nos. **15, 17–20, 23, 24, 29, 33–36.**

+Pl. 15, fig. 16.—*Locality:* Many stations throughout the whole series.

+Pl. 15, fig. 19.—*Locality:* No. 43.

Lagena acuticosta Reuss (Pl. 15, fig. 20).

Lagena acuticosta Reuss, 1861, p. 305, pl. 1, fig. 4.

An unsatisfactory species, for it is linked closely with *L. costata* on the one hand, and *L. sulcata* on the other.—*Locality:* Many stations up to No. **22**; afterwards extremely rare.

Pl. 15, fig. 20. An odd specimen, probably a very weak form. —*Locality:* Uncertain.

+Pl. 15, fig. 22. Tests similar or nearly so occur, but they are not so large.—*Locality:* Nos. **2, 7,** and a few other stations.

Lagena melo d'Orbigny sp.

Oolina melo d'Orbigny, 1839, p. 20, pl. 5, fig. 9.

There are several fine typical examples and a few small ones on the slide, but as they are mixed with other varieties the locality cannot be determined.

The form with the cross-bars sunk, which is assigned by Reuss to *L. catenulata* Williamson, 1862 (1863), pl. 6, fig. 75, is also present.

Lagena hexagona Williamson sp. (Pl. 15, figs. 21–23).

Entosolenia squamosa var. *hexagona* Williamson, 1848, p. 20, pl. 2, fig. 23.

Very many beautiful specimens occur; some are globular, others pyriform, with and without necks. The depth and size of the mesh vary greatly.

A few, which I take to be *L. geometrica* Reuss, 1862 (1863), pl. 5, fig. 74, are exquisite, although the arrangement of their cells is not always parallel. The cells are deep, and their sides exceedingly delicate. Several have short necks. I have not attempted to draw them, as I could not have produced the

desired effect.—*Locality:* Again the mixing of the varieties prevents me from giving any definite information.

There are a few which appear to be the same as the one figured by Brady in the *Challenger* Report, pl. 58, fig. 33, of which the angles of the cells tend to become spinous, especially at the base of the test. This peculiarity seems to be feebly indicated in Brady's figure.

Pl. 15, fig. 21. Several of this elegant form occur.—*Locality:* Uncertain.

Pl. 15, fig. 22. A globular variety.

Pl. 15, fig. 23. A compressed variation of the above, but of smaller size. These two forms are placed together on the slide. —*Locality:* Taking the two forms together they are marked Nos. **2–5, 13, 17–20, 44.**

Lagena squamosa Montagu sp.

Vermiculum squamosum Montagu, 1803, *Test. Brit.* p. 526, pl. 14, fig. 2.

A few only are present.—*Locality:* Uncertain.

Lagena exsculpta Brady.

Lagenulina sulcata Terquem, 1876, *Anim. sur la Plage de Dunkerque*, fasc. 2, p. 68, pl. 7, fig. 9.

Lagena exsculpta Brady, *Quart. Journ. Micr. Sci.*, vol. xxi., N.S., p. 61.

Lagena exsculpta Brady, 1884, p. 467, pl. 58, fig. 1; pl. 61, fig. 5.

Five examples found, and they are compressed. Three of them are in poor condition. These latter are not quite typical, as the sculpture becomes irregular at the base.—*Locality:* Nos. **37, 39.**

Lagena sulcata Walker and Jacob sp. (Pl. 15, figs. 24, 25).

Serpula (*Lagena*) *striata sulcata rotunda* Walker and Boys, 1784, p. 2, pl. 1, fig. 6.

Serpula (*Lagena*) *sulcata* Walker and Jacob, 1798, p. 634, pl. 14, fig. 5.

This common foraminifer is well represented. In some the body of the test is globular, and in others cylindrical. Apicu-

late forms also occur.—*Locality :* Nos. **4, 14, 15, 20, 24, 26, 38, 42-44**, and a few others.

Pl. 15, fig. 24. This is closely allied to *L. alifera* Reuss, 1870, p. 467.—Von Schlicht, 1870, pl. 3, figs. 15, 16, 21, 22.—*Locality :* Nos. **3, 10**, and two or three others.

Pl. 15, fig. 25. This form, known as *L. sulcata* var. *interrupta* Williamson, is hardly worthy of a varietal name, as it is not at all uncommon for some of the costae or striae, both in *L. sulcata* and *L. striata*, to be shorter than the others.

Lagena plumigera Brady (Pl. 15, fig. 26).

Lagena plumigera Brady, 1881, *Quart. Journ. Micr. Sci.*, vol. 21, N.S., p. 62.

Lagena plumigera Brady, 1884, p. 465, pl. 58, figs. 25, 27.

Two of the tests are similar to the one figured; several others are smaller and much damaged.—*Locality :* Nos. **1, 2, 43**.

Lagena semilineata Wright (Pl. 15, fig. 27).

Lagena semilineata Wright, 1884-5, App. 9, 1886, p. 320, pl. 26, fig. 7.

Evidently a bold form of *L. semilineata*.—*Locality :* Three examples at Station No. **2**.

Lagena gracilis Williamson.

Lagena gracilis Williamson, 1848, p. 13, pl. 1, fig. 5.

This protean species is found at many stations throughout the whole series. All the forms represented in the *Challenger* Report, 1884, appear to be present. No line of demarcation can be drawn between this species and apiculate forms of *L. sulcata* and *L. striata*; they are also linked with *L. distoma* Parker and Jones.

Lagena quinquelatera Brady.

Lagena quinquelatera Brady, 1881, *Quart. Journ. Micr. Sci.*, vol. 21, N.S., p. 60.

Lagena quinquelatera Brady, 1884, p. 484, pl. 61, figs. 15, 16.

I take this to be a variety of *L. gracilis*.

Two specimens only.—*Locality :* No. 2.

Lagena semistriata Williamson.

Lagena striata var. *β semistriata* Williamson, 1848, p. 14, pl. 1, figs. 9, 10.

The great majority are small. Some have the neck bent to one side and the body slightly curved. A few are cylindrical and others have the contour of *L. clavata* d'Orbigny.—*Locality :* Nos. **1, 20–22, 29, 42–44.**

Lagena crenata Parker and Jones var. (Pl. 15, fig. 28).

Lagena crenata Parker and Jones, 1865, p. 420, pl. 18, fig. 4.

They are not typical, but I think they are best placed under the above heading. The projecting parts at the base run partly towards its centre as blades. The neck is not decorated. A few of the examples are not so slim as the one figured, and have their sides slightly convex. Thirteen specimens occur. I cannot give all the stations at which they are found, but the following may be indicated. *Locality :* **22, 43.**

Lagena Thornhilli Sidebottom (Pl. 15, fig. 29).

Lagena Thornhilli Sidebottom, 1912, *Journ. Q. M. C.*, p. 390, pl. 15, fig. 26.

They differ slightly from the one figured at the above reference, for the upper parts of the wings are joined together so as to form a hood, as shown in the figure. In one of the examples the three cavities formed by the hood are blocked with exogenous shell-growth.

Four examples occur.—*Locality :* **6, 8, 29.**

Lagena stelligera Brady.

Lagena stelligera Brady, 1881, *Quart. Journ. Micr. Sci.*, vol. 21, N.S., p. 60.

Lagena stelligera Brady, 1884, p. 466, pl. 57, figs. 35, 36.

A good many agree with Brady's *Challenger* figure, pl. 57, fig. 35, but some are more slender, and several are very minute.

See remarks, † pp. 391, 392.—*Locality :* Nos. **5, 14, 17–19, 21,**

22, also Nos. 23, 24, 29, 32, 33, 35, 37, 39–41. From these latter stations a few of the "nude" form were obtained.

+ Pl. 16, fig. 1. In most of the specimens, some of the costae are more prominent than the others, but none of them are "interrupted," as in the figure referred to.—*Locality:* 10, 22–24, 36, 39.

+ Pl. 16, fig. 2. Numerous examples of this "nude" variety are on the slides, some having very long, delicate necks. The apiculate portion varies both in width and length. Two very large tests were found, and except for the absence of the costae they agree well with the *Challenger* figure, pl. 57, fig. 36.—*Locality:* Nos. 2, 3, 5, 12, 19, 23, 24, 29, 32, 33, 35, 36, 38–40.

+ Pl. 16, fig. 3.—*Locality:* Nos. 3–7, 9, 10, 13, 17, 23, 24, 26, 29, 33–35, 39, 40.

+ Pl. 16, fig. 4. Compressed. Nine examples found.—*Locality*: Nos. 2, 24. Other stations uncertain.

Lagena stelligera Brady var. *eccentrica* Sidebottom (Pl. 15, fig. 30).

Lagena stelligera Brady var. *eccentrica* Sidebottom 1912, *Journ. Q. M. C.*, p. 392, pl. 16, figs. 5, 6.

Pl. 15, fig. 30. On this specimen the ridge at the base is scarcely perceptible. Two or three only found.—*Locality:* Uncertain.

+ Pl. 16, fig. 5. Not typically represented in these gatherings.

+ Pl. 16, fig. 6. The examples generally have the ridge at the base carried farther up the side of the test.—*Locality:* Nos. 11, 14, 37.

Lagena stelligera Brady var. *eccentrica* Sidebottom, compressed form (Pl. 15, fig. 31).

This is the compressed form, and some of the specimens from No. 43 are in fine condition.—*Locality:* Nos. 10, 13, 14, 19, 20–43. Very rare, except at No. 43.

Lagena striatopunctata Parker and Jones.

Lagena sulcata var. *striatopunctata* Parker and Jones, 1865, p. 350, pl. 13, figs. 25–27.

Various forms are present. Some have the neck bent to one side, others have only a very short neck. The body of the test

also varies greatly, being occasionally almost globular.—*Locality :* Nos. **1–3, 22, 24–26, 33, 34, 38, 42, 43.**

Lagena striatopunctata Parker and Jones (?) var. *complexa* Sidebottom.

Lagena striatopunctata Parker and Jones (?) var. *complexa* Sidebottom, 1912, *Journ. Q. M. C.*, p. 393, pl. 16, fig. 11.

† Pl. 16, fig. 11. None of the tests are in perfect condition, all showing signs of the disintegration mentioned at the above reference.—*Locality :* Nos. **7, 9, 24.**

Lagena striatopunctata Parker and Jones var. *inaequalis* Sidebottom.

Lagena striatopunctata Parker and Jones var. *inæqualis* Sidebottom, 1912, *Journ. Q. M. C.*, p. 393, pl. 16, fig. 12.

Three tests are on the slide, but only two belong to this variety. —*Locality :* Two of the following, Nos. **4, 10, 11.**

Lagena striatopunctata Parker and Jones var. *spiralis* Brady.

Lagena spiralis Brady, 1884, p. 468, pl. 114, fig. 9.

Locality : Nos. **1–4, 22, 37, 38, 43, 44.** Very rare except at No. **1.**

Lagena Fieldeniana Brady.

Lagena Fieldeniana Brady, 1878, *Ann. Mag. Nat. Hist.* (5) vol. 1, p. 434, pl. 20, fig. 4.
Lagena Fieldeniana Brady, 1884, p. 469, pl. 58, figs. 38, 39.

A solitary, rather rotund example, of which the neck is broken off short.—*Locality :* Uncertain.

Lagena desmophora Rymer Jones.

Lagena vulgaris var. *desmophora* Rymer Jones, 1872, p. 54, pl. 19, figs. 23, 24.

The specimens are typical and in good condition. All are, or have been, apiculate. The number of spines at the base varies from one to four.—*Locality :* Nos. **2, 5, 7–11, 13, 33, 40.**

Lagena foveolata Reuss.

Lagena foveolata Reuss, 1862 (1863), p. 332, pl. 5, fig. 65.
Lagena No. 25, von Schlicht, 1870, p. 10, pl. 3, fig. 25.

Three or four only occur. The sculpture of the test is exceedingly fine.—*Locality :* No. **43**, and one or two other stations which are uncertain.

Lagena foveolata Reuss var.

Lagena foveolata Reuss var. Sidebottom, 1912, *Journ. Q. M. C.*, p. 395, pl. 16, figs. 16, 17.

It is possible that further investigation may reveal this to be an apiculate form of one of the variations of *L. melo* d'Orbigny sp.—*Locality :* Nos. **1**, **2**, **4**, **6**, **8**, **10**, **12**, **14**, **15**, **17**, **19**, **21**, **22**, **24**, **33**, **36**, **38**, **40**, **42–44**.

Lagena foveolata Reuss var. *spinipes* Sidebottom.

Lagena foveolata Reuss var. *spinipes* Sidebottom, 1912, *Journ. Q. M. C.*, p. 396, pl. 16, figs. 18–20.

The tests are not in the best condition, and in some instances the spines appear to be absent, or scarcely perceptible. The rotund form does not occur.—*Locality :* Fifteen specimens at at No. **2**, three at No. **3**, four at No. **4**.

Lagena foveolata Reuss (?) var *paradoxa* Sidebottom (Pl. 15, fig. 32).

Lagena foveolata Reuss (?) var. *paradoxa* Sidebottom, 1912, *Journ. Q. M. C.*, p. 395, pl. 16, figs. 22, 23.

This is one of the commonest foraminifera in these gatherings. The tests vary greatly in size and shape.—*Locality :* Nos. **1–22**, (except No. **17**), **23–26**, **29**, **31**, **33**, **34–36**, **39–41**, **44**.

Lagena lamellata Sidebottom.

Lagena lamellata Sidebottom, 1912, *Journ. Q. M. C.*, p. 396, pl. 16, figs. 24, 25.

I can only identify four tests.—*Locality :* Two occur at No. **43**; the other station or stations are uncertain.

Lagena Hertwigiana Brady (Pl. 15, fig. 33).

Lagena Hertwigiana Brady, 1881, *Quart. Journ. Micr. Sci.*, vol. 21, N.S., p. 62.
Lagena Hertwigiana Brady, 1884, p. 470, pl. 58, fig. 36.

The figure in my copy of the *Challenger* Report, pl. 58, fig. 36, does not show the reticulation referred to in the description of the species in the text, p. 470. In the three or four specimens found in these soundings, the surface is roughened and the perforations show very plainly.—*Locality :* Uncertain, with the exception of No. **43**.

Lagena Hertwigiana Brady var. *undulata* Sidebottom.

Lagena Hertwigiana Brady var. *undulata* Sidebottom, 1912, *Journ. Q. M. C.*, p. 397, pl. 16, figs. 26–28.

Many examples occur.—*Locality :* Nearly all the stations, but chiefly Nos. **2, 7, 10, 17, 24, 34, 43**.

Lagena pacifica Sidebottom.

Lagena pacifica Sidebottom, 1912, *Journ. Q. M. C.*, p. 398, pl. 16, fig. 29.

Only two or three specimens found.—*Locality :* Uncertain.

Lagena splendida sp. nov. (Pl. 16, figs. 1–3).

I am quite at a loss how to describe this exquisite Lagena adequately, and I am unable to draw it owing to the complexity of its decoration, which is exceedingly minute. The test glistens and most probably it has been apiculate. The neck is fractured. There is a second specimen which I think is the same, but there is a slight difference in its appearance which I am unable to explain. It is apiculate.—*Locality :* Uncertain.

Note.—Not being able to get a satisfactory definition with my microscope, I submitted the test to Mr. Earland for examination, who had better means of lighting up the test than I had. His observations were made with the assistance of a Zeiss vertical illuminator and daylight instead of artificial light. He writes as follows :

"The markings appear to be knife-edged costae, from one side of which triangular processes project at intervals. The apex of the process barely touches the inner side of the adjoining costa. . . . The triangular processes are flush with the costae at their base, but apparently sink away towards the apex, which is probably but little raised above the wall of the test. The sunken parts between the processes have a matt surface, whereas the processes and costae are quite translucent."

I may say that my own examination of the test agrees to a great extent with the above, but I think the edges of the costae are waved (see Pl. 16, fig. 3).

In a second communication Mr. Earland writes: "I succeeded in getting a stereoscopic view of the shell under a $\frac{1}{4}$ in. yesterday, and it gave rather a fresh view of its structure. It seemed to be covered with lines of pyramidal points in broken lines. Each pyramid is a blunt spine."

I have not succeeded, however, in seeing these characters of the test.

The figure (Pl. 16, fig. 2) gives the effect of what I think I see under the microscope, and it coincides to a great extent with Mr. Earland's first description, though the details given in his second communication do not appear to me to be necessarily contradictory. I wish to acknowledge my sense of the trouble Mr. Earland has taken in the matter.

Lagena spumosa Millett (Pl. 16, fig. 4).

Lagena spumosa Millett, 1901, p. 9, pl. 1, fig. 9.

Most of the tests are slightly curved at the oral end, but the "bird's-clawlike" process is more slender than is indicated in Mr. Millett's illustration. Several are more elongate than the one figured.—*Locality:* Frequent at No. **22**; Nos. **24, 38, 40, 42, 43**, and a few other stations.

Lagena spumosa Millett, var.

Lagena spumosa Millett var. Sidebottom, 1912, *Journ. Q. M. C.*, p. 398, pl. 16, fig. 30.

It is curious that the aboral end of the test appears to have been slightly abraded, I think in all cases.—*Locality:* Nos. **4, 6, 7, 10, 11, 13, 24, 25, 33, 35, 39, 40, 42, 43.**

Lagena Chasteri Millett.

Lagena Chasteri Millett, 1901, p. 11, pl. 1, fig. 11.

See my remarks on the type-form ÷ p. 398.

Lagena Chasteri Millett (var. ?).

Lagena Chasteri Millett (var. ?) Sidebottom, 1912, *Journ. Q. M. C.*, p. 398, pl. 16, figs. 32–34.

Many occur, but I am quite unable to separate this variation from the type, for the curious little "stopper" at the orifice is never so pronounced as in Mr. Millett's figure, and is often apparently absent. Taking the type-form and the variation together, for they are mixed on the slides, they occur as follows:—*Locality:* Nos. **1–4, 22, 34, 38,** and frequently at Nos. **42–44.**

Lagena pannosa Millett var.

Lagena pannosa Millett var. 1901, p. 11, pl. 1, fig. 14.

It is probable that two or three examples of this variation are present.—*Locality:* Uncertain.

Lagena intermedia Sidebottom.

Lagena intermedia Sidebottom, 1912, *Journ. Q. M. C.*, p. 399, pl. 17, figs. 1–3.

Locality: Nos. **3, 11, 12, 23, 24, 29, 32, 39–41.**

Lagena quadralata Brady.

Lagena quadralata Brady, 1881, *Quart. Journ. Micr. Sci.*, vol. xxi. (N.S.), p. 62.

Lagena quadralata Brady, 1884, p. 464, pl. 61, fig. 3.

In the *Challenger* Report Brady states that this Lagena is allied to the *Lagena alifera* of Reuss. I should prefer to consider it as a variety of *L. lagenoides* Williamson var. *tenuistriata* Brady, for we know that this latter occurs in the trifacial condition (see ÷ Pl. 19, fig. 5), and therefore it is not surprising to find it with four equidistant keels; also I have a good example of *L. lagenoides* with five equidistant keels. The specimen found is very small and not in the best condition. I think the wings are tubular, but cannot be certain. On the same slide there

are two examples with three keels, and two with five keels.—*Locality:* One specimen at No. **1**. Other stations uncertain.

Note.—One or two examples occur with four keels which are not tubulated. These I should place as a variety of *L. striata*.

Lagena sp. incert.

Lagena sp. incert. Sidebottom, 1912, *Journ. Q. M. C.*, p. 399, pl. 17, figs. 4, 5.

Locality: Three examples at No. **2**, two at No. **24**.

Lagena laevigata Reuss, sp. (Pl. 16, fig. 5).

Fissurina laevigata Reuss, 1850, p. 366, pl. 46, fig. 1.

Large and small examples of the type-form occur, but they are not numerous. It is impossible to separate *L. laevigata* from *L. acuta*, as the one passes insensibly into the other. Many other examples are present in which the orifice is not central. Forms ranging round *Fissurina oblonga* Reuss, 1862 (1863), pl. 7, fig. 89, are frequent, and are found at many stations. A few specimens occur that are circular in outline.

Pl. 16, fig. 5. There are two sets of these and they vary a little. Some have the appearance of being subcarinate, but this seems to be caused by the test being clearer at its edge than at any other part. Only two or three examples have the spines at the orifice well developed, and most have a small wing at either side of the neck. There is no internal tube.—*Locality:* Nos. **42–44**.

Note.—These are not far removed from *L. falcata* Chaster, 1892, p. 6, pl. 1, fig. 7. On another square (locality uncertain) there is one typical form, and there are also one or two others that are carinate at the base, which seem to be intermediate between *L. falcata* and Mr. Millett's figure of *L. marginata* var. Millett, 1901, p. 497, pl. 8, fig. 21.

Lagena laevigata Reuss sp. var. *virgulata* Sidebottom (Pl. 16, fig. 6).

Lagena laevigata Reuss sp. var. *virgulata* Sidebottom, 1912, *Journ. Q. M. C.*, p. 400, pl. 17, fig. 8.

Pl. 16, fig. 6. A few fine examples placed amongst others which are too opaque for me to be certain whether they belong to this variation.—*Locality:* Uncertain.

Lagena laevigata Reuss sp. var.

Lagena laevigata Reuss sp. var. Sidebottom, 1912, *Journ. Q. M. C.*, p. 400, pl. 17, fig. 7.

+Pl. 17, fig. 7. Very rare.—*Locality :* Nos. **15, 34.**

Lagena acuta Reuss sp. (Pl. 16, fig. 7).

Fissurina acuta Reuss, 1862, p. 340, pl. 7, fig. 90, and *F. apiculata*, p. 339, pl. 6, fig. 85.

Lagena acuta (including such as have only the slightest indication of the apiculate process) is found at almost all the localities. The size and inflation of the tests, as well as their outlines, vary greatly.—Two at No. **14.**

Lagena acuta Reuss sp. var. (Pl. 16, fig. 8).

The chief feature of this variety is the curious oval marking at the base, on both sides of the test. It is very rarely so clearly shown as in the drawing. The tests are opaque or nearly so, and when the shell-substance becomes very dense the markings disappear, but if damped some trace of them can be detected.—*Locality :* Nos. **3–7, 9–11, 13–15, 29, 33, 34, 39, 40, 42, 44.**

+Pl. 17, fig. 9. The mixing of this form with that of fig. 10 prevents me from giving the exact localities, but it is evidently rather rare. They correspond with the *Fissurina apiculata* Reuss, 1862, p. 339, pl. 6, fig. 85.

Lagena acuta Reuss sp. var. *virgulata* Sidebottom.

Lagena acuta Reuss sp. var. *virgulata* Sidebottom, 1912, *Journ. Q. M. C.*, p. 401, pl. 17, fig. 10.

+Pl. 17, fig. 10. This appears to occur at nearly all the stations up to No. **22**, after which it is extremely rare.

Lagena acuta Reuss sp. var.

Lagena acuta Reuss sp. var. Sidebottom, 1912, *Journ. Q. M. C.*, p. 401, pl. 17, fig. 11.—

Locality : Nos. **3, 4, 6, 10, 11, 14, 24, 25, 34, 39.**

Lagena lucida Williamson sp. (Pl. 16, fig. 9).

Entosolenia marginata var. *lucida* Williamson, 1848, p. 17, pl. 2, fig. 17.

There are nine examples which are nearly circular in outline, and subcarinate.—*Locality :* No. **44**.

Pl. 16, fig. 9. I believe this to be an elongate form of *L. lucida*, in which the characteristic markings are only feebly represented. The shell is very little compressed. Two or three specimens only occur.—*Locality :* Uncertain.

One or two tests are present which are intermediate between the type and the elongate form referred to above. Several are apiculate.—*Locality :* Nos. **1, 6, 14, 21, 22, 24, 38, 42, 43.**

Lagena multicosta Karrer sp.

Fissurina multicosta Karrer, 1877, p. 379, pl. 16 *b*, fig. 20.
Fissurina bouei Karrer, p. 378, pl. 16 *b*, fig. 19.

The examples are small, and some are without the irregularity of the costae characteristic of the type.—*Locality :* Nos. **24, 29, 34, 35, 39, 42–44**, and one or two of the earlier stations.

Lagena fasciata Egger sp. (Pl. 16, figs. 10–13).

Oolina fasciata Egger, 1857, p. 270, pl. 5, figs. 12–15.

Pl. 16, fig. 10. Beautiful specimens occur which have the mouth protruding, and the orifice composed of a line of pores. The bands are flush or nearly so. Large and small tests are on the slide.—*Locality :* Nos. **1, 3–5, 7, 10, 22, 44**, and several other stations which are uncertain.

Pl. 16, fig. 11. An apiculate form which is extremely rare. The edge of the test is flattened, and has a very fine groove running down its centre. The orifice appears to be composed of a line of pores.—*Locality :* Uncertain.

Pl. 16, fig. 12. Slightly apiculate, the orifice large, and the entosolenian tube divided at the end. The edges of the bands, which are not interrupted at the base, appear to be somewhat raised. When the test is opaque it is difficult to make out the bands.—*Locality :* Nos. **24, 34, 36, 43, 44**; frequent at No. **44**.

Pl. 16, fig. 13. The test is apiculate and the opaque bands which appear to be flush with the surface are continuous—that is,

not interrupted at the base as is usual in the type-form. About thirty specimens on the slide.—*Locality :* Nos. **42–44.**

Lagena fasciata Egger sp. var. *spinosa* Sidebottom.

Lagena fasciata Egger sp. var. *spinosa* Sidebottom, 1912, *Journ. Q. M. C.*, p. 402, pl. 17, figs. 16, 17.

+ Pl. 17, fig. 16. One or two small specimens.—*Locality :* Uncertain.

+ Pl. 17, fig 17. A fair number are present, but they are mixed with *L. staphyllearia*, so I cannot give the localities. See remarks + p. 402.

Lagena fasciata Egger sp. var. *carinata* Sidebottom (Pl. 16, figs. 14–16).

Lagena fasciata Egger sp. var. *carinata* Sidebottom, 1906, *Mem. Pro. Lit. Phil. Soc.*, Manchester, No. 5, p. 7, pl. 1, fig. 17.

Lagena fasciata Egger sp. var. *carinata* Sidebottom, 1912, *Journ. Q. M. C.*, p. 403, pl. 17, fig. 18.

Pl. 16, fig. 14. The test is compressed, and the keel becomes more pronounced as it approaches the base of the shell. The internal tube is attached to the back of the test. A few of the examples are very fine, like the one chosen for illustration. The curved bands seem to be nothing more than an innumerable number of pores showing distinctly. In some of the smaller examples these bands can hardly be distinguished. It is open to question if these forms and the following (Pl. 16, fig. 15) would not be better placed under *L. marginata.*—*Locality :* Nos. **1–3, 5–7, 10, 11, 13–22.**

Pl. 16, fig. 15. Test compressed, carinate. The entosolenian tube is long and curled at its end. The bands are faintly marked as in the preceding form.—*Locality :* Nos. **2–5** ; common at No. **2.**

Pl. 16, fig. 16. A solitary example. The edges of the curved bands are very slightly raised, and the shell becomes more compressed as the orifice is approached. The keel is represented by a fine ridge only. The specimen is not in a very good condition, opaque patches interfering with the definition of the bands, especially at their bases.—*Locality :* No. **42.**

+ Pl. 17, fig. 18. Two or three examples found. The carina is not pointed at the base as in the figure referred to.—*Locality :* Uncertain.

Lagena staphyllearia Schwager sp.

Fissurina staphyllearia Schwager, 1866, p. 209, pl. 5, fig. 24.

The non-carinate form is rare. The number of spines varies. The tube is attached to one side, thus causing the orifice to be eccentric. In a few instances of the carinate variety, where only two spines are present, it is impossible to separate them from the *Fissurina bicaudata* Seguenza, which is generally placed with *L. marginata*.—*Locality :* Nos. **1–7, 9–12, 15–25, 29, 33, 34, 36, 37, 39–43.**

The variety with either the keel or the lower part of the test serrated or partially fimbriated is not so frequent, but occurs at many localities. The orifice is central and the sides of the test are only slightly carinate.—*Locality :* Nos. **5–8, 10, 11, 14, 15, 18, 19, 21, 22, 24, 33, 34, 40, 43.**

÷ Pl. 17, fig. 19. Very rare.—*Locality :* Nos. **2, 3, 15, 22.**

÷ Pl. 17, fig. 21. This peculiar variety is rather rare. The tests are semi-opaque. There is a short entosolenian tube.—*Locality :* Nos. **5–11, 13, 21, 23, 25, 36, 39, 40.**

÷ Pl. 17, figs 22, 23. See remarks ÷ p. 403.—*Locality :* Nos. **4–6, 8, 10, 22, 23, 33, 39.**

Lagena staphyllearia Schwager sp. var. *quadricarinata* Sidebottom.

Lagena staphyllearia Schwager sp. var. *quadricarinata* Sidebottom, 1912, *Journ. Q. M. C.*, p. 404, pl. 21, fig. 16.

Locality : Nos. **2, 5–7, 9, 10, 12, 13, 21, 38, 41.**

Lagena unguiculata Brady.

Lagena unguiculata Brady, 1881. *Quart. Journ. Micr. Sci.*, vol. 21, (N.S.), p. 61.

Lagena unguiculata Brady, 1884, p. 474, pl. 59, fig. 12.

See remarks ÷ p. 404.—*Locality :* Nos. **5–10.**

Lagena quadrata Williamson sp.

Entosolenia marginata var. *quadrata* Williamson, 1858, p. 11, pl. 1, fig. 27.

Both the carinate and non-carinate form are present.—*Locality :* Nos. **15, 22, 24, 25, 34, 37, 40, 42–44.**

There are several examples which have a short neck and the orifice carrying a short spine at either side. Three or four specimens are similar to the one figured by Mr. Millett in his Malay Report, 1901, p. 496, pl. 8, fig. 18.

Lagena marginata Walker and Boys sp. (Pl. 16, figs. 17–20, fig. 18, trifacial form).

"*Serpula* (*Lagena*) *marginata*" Walker and Boys, 1784, p. 2, pl. 1, fig. 7.

This species is exceedingly well represented in these gatherings, and in one form or another is found at nearly all the stations. The shape of the body of the test varies from flattened to globular, and in outline from circular to elongate-pyriform, the carination from a fine ridge to a very broad wing. The situation and form of the orifice are variable. Apiculate examples are present and some have the keel acuminate at the base.

Pl. 16, fig. 17. This agrees fairly well in outline with *Fissurina paradoxa* Seguenza, 1862, pl. 2, fig. 7. The *Fissurina bicaudata* Seguenza, 1862, pl. 2, fig. 16, is also represented, and it is difficult in some cases to separate this from *L. staphyllearia*.

Pl. 16, fig. 18. A trifacial form. If anything, the three faces of the body are somewhat concave; one would rather expect them to be convex, judging from trifacial examples that occur in other species. The specimens vary very little.—*Locality:* Nos. **2–4, 8–10, 14, 15, 22, 29, 34, 36, 39, 40.**

Pl. 16, fig. 19. The edge of the test is flattened, the orifice fissurine. In some positions it has the appearance of being slightly bicarinate, but I do not think it is so.—*Locality:* Nos. **42, 43.**

Pl. 16, fig. 20. This minute variety has a comparatively large orifice, which is much compressed and opens out on one side of the median line; the tube is attached to the back of the test, which is very slightly carinate. The test is moderately compressed and curiously tucked in at its base. The specimens are mixed with others very similar to them, but which have the orifice central and the tube short and straight. There are other forms on the same square, so I cannot give the exact localities. The two forms mentioned are rare. Both were found at a station later in the series than No. **22.**

Lagena compresso-marginata Fornasini (Pl. 16, fig. 21).

Lagena compresso-marginata Fornasini, 1889, *Minute Forme di Riz. Retic. nella Marna Plioc. del Ponticello di Savena*, Bologna, fig. 16.

Pl. 16, fig. 21. This is rather a stoutly-built form. The aperture is fissurine and the test apiculate.—*Locality :* Nos. **22, 24.** Rather rare.

There are a few very small examples that appear to be almost identical with Fornasini's figure.—*Locality :* Uncertain.

+ Pl. 17, fig. 30. Only two or three found.—*Locality :* Nos. **42, 44,** and two or three examples at one or two other stations.

+ Pl. 17, fig. 31. Very rare.—*Locality :* Nos. **2, 4.**

+ Pl. 18, fig. 1. Very rare. See remarks + p. 406.—*Locality :* Nos. **2, 5, 7, 19, 24.**

Lagena marginata Walker and Boys var.

Lagena marginata Walker and Boys var. Sidebottom, 1912, *Journ. Q. M. C.*, p. 407, pl. 18, figs. 4, 5.

Locality : Nos. **4–6, 10–13, 16, 17, 19–23, 25, 36, 40.**

Lagena marginata Walker and Boys var. *catenulosa* Chapman (Pl. 16, fig. 22).

Lagena marginata var. *catenulosa* Chapman, 1895, p. 28, pl. 1, fig. 5.
Lagena marginata Walker and Boys var. *catenulosa* (Chapman) Sidebottom, 1912, *Journ. Q. M. C.*, p. 407, pl. 18, fig. 6.

Pl. 16, fig. 22. Four examples occur. The one chosen for illustration hardly shows a trace of the chain-pattern, and the test is free from exogenous shell-growth. The others show the chain-pattern. One of the specimens has the body of the test covered with exogenous beads. The few tubuli shown in the drawing are caused, I believe, by the borings of some animal.—*Locality :* Nos. **1, 5, 10.**

Lagena marginata Walker and Boys var. *raricostata* Sidebottom.

Lagena marginata Walker and Boys var. *raricostata* Sidebottom, 1912, *Journ. Q. M. C.*, p. 408, pl. 18, figs. 8, 9.

+ Pl. 18, fig. 8. Over twenty specimens are on the slide.—*Locality :* Nos. **1–3.**

Lagena marginata Walker and Boys var. *striolata* Sidebottom.

Lagena marginata Walker and Boys var. *striolata* Sidebottom, 1912, *Journ. Q. M. C.*, p. 408, pl. 18, figs. 10, 11.

† Pl. 18, fig. 10.—*Locality :* Nos. **1, 3, 4, 15, 18–20, 22–25, 34, 35, 38, 42–44** ; frequent at Nos. **42, 43.**

† Pl. 18, fig. 11.—*Locality :* Nos. **23, 24, 42.**

Lagena marginata Walker and Boys var. *elegans* Sidebottom.

Lagena marginata Walker and Boys var. *elegans* Sidebottom, 1912, *Journ. Q. M. C.*, p. 409, pl. 18, fig. 12.

Locality : Nos. **14, 19, 20** ; frequent at No. **14.**

Lagena marginata Walker and Boys var. *retrocostata* Sidebottom.

Lagena marginata Walker and Boys var. *retrocostata* Sidebottom, 1912, *Journ. Q. M. C.*, p. 409, pl. 18, fig. 13.

Locality : One specimen at No. **2**, and one other, station uncertain.

Lagena marginata Walker and Boys var. *semimarginata* Reuss.

Lagena No. 64, von. Schlicht, 1870, p. 11, pl. 4, figs. 4–6 ; and *No. 65*, p. 11, pl. 4, figs. 10–12.
Lagena marginata var. *semimarginata* Reuss, 1870, p. 468.

An altogether unsatisfactory variation. It occurs in several forms at a few stations ; that figured in the *Challenger* Report, pl. 59, fig. 19, occurs at No. **44.**

Lagena marginata Walker and Boys var. *seminiformis* Schwager.

Miliola stiligera Ehrenberg (?) 1854, pl. 31, fig. 6.
Lagena seminiformis Schwager, 1866, p. 208, pl. 5, fig. 21.

Four large examples occur, similar to those figured in the *Challenger* Report, pl. 59, figs. 28–30.—*Locality :* Nos. **5, 16, 17.**

+ Pl. 18, fig. 16. Extremely rare, only one or two being found. —*Locality :* Uncertain.

+ Pl. 18, fig. 17.—*Locality* : Nos. **1–3, 15**. Three examples at two or perhaps three of the four stations indicated ; also six at a few other uncertain localities.

+ Pl. 18, fig. 18.—*Locality :* Nos. **1, 3, 13,** and several others. Very rare.

+ Pl. 18, fig. 19. Several have the central spine at the base of the same length as the other two.—*Locality :* Nos. **2, 3, 6–8, 10, 11, 24, 34–36.**

Lagena marginato-perforata Seguenza (Pl. 16, figs. 23–25).

Lagena marginato-perforata Seguenza, 1880, p. 332, pl. 17, fig. 34.

Very numerous. The variety with no keel is rare. The shape of the test varies a good deal as regards compression and length. In a few cases, fine lines, running the length of the test, make their appearance. At the edge of the test, the markings are sometimes arranged in a line.—*Locality :* Nos. **1, 2, 4, 5, 7–15, 19, 20, 22–25, 29, 38–40, 42–44.**

Pl. 16, fig. 23. This is nearly circular in section near the base, and becomes compressed as the orifice is approached. Tube straight. Rare.—*Locality :* No. **14.**

Pl. 16, fig. 24. In this example fine pores are seen, but with few exceptions the centre of each face of the test is free from them. One specimen is in the trifacial condition.—*Locality :* Nos. **23–25, 29, 33, 36, 38, 39.**

Pl. 16, fig. 25. Test well compressed, subcarinate. Except for the two lines of pores that run round the test close to its edge, the faces are almost free from them. The shell is partially clouded. Fairly frequent.—*Locality :* Uncertain.

Lagena Wrightiana, Brady.

Lagena Wrightiana Brady, *Quart. Journ. Micr. Sci.*, vol. 21, 1881, p. 62.

Lagena Wrightiana Brady, 1884, p. 482, pl. 61, figs. 6, 7.

The central part of the faces of the test is not always smooth. Very rare.—*Locality :* Nos. **37, 42, 43.**

Lagena lagenoides Williamson sp. (Pl. 16, figs. 26–29, and pl. 17, fig. 1).

Entosolenia marginata Walker and Boys var. *lagenoides* Williamson, 1858, p. 11, pl. 1, figs. 25, 26.

This and its numerous variations are well represented. Pl. 16, figs. 26, 27. I was tempted to place these under *L. marginata*, but the appearance of the wing caused me to hesitate and to submit a specimen to Mr. Earland for examination. He reported that the wing was tubulated, being "infiltrated with amorphous carbonate of lime subsequent to the death of the animal." Mr. Millett considers that if tubuli are present "their affinity would be with *L. lagenoides* rather than with *L. marginata*." Besides the two forms figured, both large and small circular examples occur in the same condition, only with the tubuli showing more plainly.

Pl. 16, fig. 28 represents one of the small examples. There are also specimens which are apparently of exactly the same form, in which the tubuli, if present, must be extremely minute. It would appear therefore necessary to submit all such forms to critical examination.—*Locality :* Nos. **5–7, 11, 14, 15, 18–22.**

Pl. 16, fig. 29. In this instance the keel is twisted at the base. Four specimens found.—*Locality :* Uncertain, but after station No. **22.**

Pl. 17, fig. 1. The test is well compressed and the orifice also. Entosolenian tube short and curled.—*Locality :* Nos. **42–44**; frequent at Nos. **43, 44.**

† Pl. 18, fig. 22. The form occurring is very similar to the figure referred to. It is rather smaller and the keel is narrower and thicker; the neck and phialine orifice are the same.—*Locality :* Nos. **1–3, 42–44.**

Six large specimens similar to the *Challenger* Report figure, pl. 60, fig. 14, are also present. Very rare.—*Locality :* Nos. **2, 22, 24.**

Another set is similar to † pl. 19, fig. 4, but the tests are not striated. Frequent.—*Locality :* Nos. **2–8, 11.**

† Pl. 18, fig. 23. See remarks, † p. 412.—*Locality :* Nos. **2, 36, 38, 39.**

† Pl. 18, fig. 29. Typical examples are very rare and not so

large as the specimen referred to.—*Locality:* No. **3**, and either No. **35** or **39**.

Besides the above, there are a few specimens which are much smaller, especially in the width of the test.—*Locality:* Nos. **17**, **19**, and one or two other stations.

Lagena lagenoides Williamson sp. var. nov. *duplicata* (Pl. 17, fig. 2).

The test is bicarinate; aperture oval and the keels tubulated. Six specimens found.—*Locality:* Nos. **24**, **37**.

Lagena lagenoides Williamson sp. var. *tenuistriata* Brady.

Lagena tubulifera var. *tenuistriata* Brady, 1881, *Quart. Journ. Micr. Sci.* vol. 21 (N.S.), p. 61.

Lagena lagenoides Williamson var. *tenuistrata* Brady, 1884, p. 479, pl. 60, figs. 11, 15, 16.

÷Pl. 19, fig. 4. Very frequent. These correspond to the *Challenger* Report, pl. 60, fig. 11. The trifacial form also occurs. —*Locality:* Nos. **1–11**, **13**, **14**, **17**, **21–24**, **29**, **31**, **33–35**, **37**, **39–41**.

There is another set of specimens which are not quite so large and have the costae on the body of the test, farther apart.—*Locality:* Nos. **14**, **15**, **17**, **18**.

There are a few large specimens very similar to the *Challenger* Report, pl. 60, fig. 15. In the stouter examples the fine costae coalesce to such an extent that the surface has a pitted appearance.—*Locality:* Nos. **2**, **8**, **11**, and one or two other stations.

Lagena formosa Schwager (Pl. 17, figs. 3–7).

Lagena formosa (pars) Schwager, 1866, p. 206, pl. 4, fig. 19.

Lagena formosa (Schwager) Brady, 1884, p. 480, pl. 60, figs. 10, 18–20.

This is present in many forms; some show the raised border punctate, others do not. See remarks ÷ p. 414.

Pl. 17, fig. 3. In this, which is obviously of the same kind as fig. 18, pl. 60, in the *Challenger* Report, the raised border is absent. Others agree with this figure, also with the *Challenger* Report, fig. 20.

Several very fine specimens are intermediate between fig. 18 and *L. formosa* var. *farosa* Brady, on the same plate, fig. 21.

They are heavily punctate at the base of the neck, and costae just start to run down the keels. Many small examples occur, which come under this unsatisfactory species, but as they are mixed on the various squares I can only give the stations for the whole series.—*Locality:* Nos. **1–8, 10, 11, 13, 14, 17, 21, 23–25, 29, 37, 39–41, 43.**

Pl. 17, fig. 4. The keel splits near the top, and the space thus formed is filled with shell-growth. The specimens are not in a satisfactory condition for examination, so I cannot say if the tubuli in the keel occupy the whole of the space. The punctate border does not seem to be raised, and it shows clearer in substance than the rest of the test. I believe this is the same as *Challenger* Report, pl. 60, fig. 10.—*Locality:* No. **44.**

Pl. 17, fig. 5. I am inclined to believe that the keel has broken away in these specimens, of which there are seven. They are all in the same condition; the drawing shows how the keel has begun to split.—*Locality:* Nos. **43, 44.**

† Pl. 18, fig. 24. I am now inclined to believe that in this case also the keel has become fractured.

Pl. 17, fig. 6. This has a likeness to the preceding pl. 17, fig. 5. The keel, which commences at the neck, soon splits and joins the two borders; the space between them is filled with shell-growth. The test has a very compact look and the tubuli show clearly. Rare.—*Locality:* Nos. **42, 43.**

Pl. 17, fig. 7. A solitary specimen in good condition. The keel, commencing at the orifice, dies away about half-way down the test. A few well-marked pores are scattered on each face of the test. At the base are several short costae.—*Locality:* No. **37.**

† Pl. 19, fig. 9. See remarks, † p. 414. Frequent.—*Locality:* Nos. **1, 2, 10, 11, 14, 17–19, 22.** Over twenty examples occur after station No. **22,** but the exact stations are uncertain.

Lagena formosa Schwager, var. (Pl. 17, fig. 8).

The drawing of this variety must be taken more or less as diagrammatic. The test, which has three keels (the central one commencing at the aperture) is in an opaque condition. The spaces between the keels are filled with shell-growth. The tubuli hardly show, unless the shell be moistened. The body of the test has fine costae running lengthwise, and is finely pitted. There

are only two specimens and they are exactly alike.—*Locality :* No. **40**.

Lagena formosa Schwager var. *comata* Brady.

Lagena formosa var. *comata* Brady, 1884, p. 480, pl. 60, fig. 22.

A few large specimens occur very similar to the *Challenger* examples, pl. 60, fig. 22.—*Locality :* Nos. **5, 6, 33, 34**.

† Pl. 19, fig. 11. A single example.—*Locality :* Uncertain.

† Pl. 19, fig. 12. Very rare.—*Locality :* Nos. **6, 10, 22,** and one or two stations which are uncertain.

Lagena squamoso-alata Brady (Pl. 18, fig. 20).

Lagena squamoso-alata Brady, 1881, *Quart. Journ. Micr. Sci.* vol. 21 (N.S.), p. 61.

Lagena squamoso-alata Brady, 1884, p. 481, pl. 60, fig. 23.

A single example occurs, which is typical, except that the produced neck is absent, having most probably been broken off.—*Locality :* No. **23**.

Pl. 18, fig. 20. Besides the above typical specimen, there are twenty-two tests which are smaller and not so robust. They answer to Brady's description of the species. The pittings on the body of the test have a tendency at times to arrange themselves in lines. The raised border appears to be punctate. It is difficult to make out the markings on the wings, owing to débris, but they can be detected in some of the specimens. I believe the wings to be cellulated. Brady, in the *Challenger* Report, only mentions that they have radiate markings ; but on examining the edges of my typical specimen it is apparent that the wings are cellulated. I take this form to be simply a variety of *L. formosa.* One example is in the trifacial condition.—*Locality :* Nos. **24, 25, 34, 36**.

Lagena quadrangularis Brady.

Lagena quadrangularis Brady, 1884, p. 483, pl. 114, fig. 11.

Lagena quadrangularis (Brady) Millett, 1901, p. 625, pl. 14, fig. 17.

A single typical specimen, but the neck appears to be fractured.—*Locality :* Either No. **14** or No. **22**.

Lagena Orbignyana Seguenza sp. (Pl. 17, figs. 9–11).

Entosolenia marginata (pars) Williamson, 1858, p. 10, pl. 1, figs. 19, 20.

Fissurina Orbignyana Seguenza, 1862, p. 66, pl. 2, figs. 25, 26.

This occurs in many forms. Some of the specimens are similar to the *Challenger* Report, pl. 59, figs. 25, 26. Numerous small varieties also are present. In some the side keels are little more than slightly raised ridges.

Pl. 17, fig. 9. This is a very neat and compact variety.

The test is moderately compressed.—*Locality:* Nos. **42–44**; frequent at Nos. **42, 44.**

Pl. 17, fig. 10. I take this to be a variety of *L. Orbignyana*, in which the central keel has split soon after leaving the orifice. The body of the test is much compressed, and is roughened. The entosolenian tube is long and attached. The split keel is entirely blocked with débris, or shell-growth. Two examples found.—*Locality:* No. **38.**

Pl. 17, fig. 11. A neat form. The central keel is emarginate at the base, at the middle of which one or two small spines project. The two subsidiary keels are not generally continuous. There are over one hundred specimens.—*Locality:* Nos. **1, 2, 4–13, 21, 23, 26, 29, 33, 34, 38, 39.**

Lagena Orbignyana Seguenza sp. var. *lacunata* Burrows and Holland (Pl. 17, fig. 12).

Lagena lacunata (Burrows and Holland) Jones, 1895, p. 205, pl. 7, fig. 12.

One set agrees exactly with fig. 1, pl. 60 of the *Challenger* Report, which Messrs. Burrows and Holland point out in the above reference, is misnamed as *L. castrensis* Schwager.—*Locality:* Nos. **42–44**; frequent at No. **44.**

A few small examples are occasionally met with in which the pittings are numerous and minute, and the keels very feebly developed.—*Locality:* Uncertain.

Pl. 17, fig. 12. I am treating this as a form of *L. Orbignyana* var. *lacunata*, but it appears to have one of the characteristics of *L. annectens* (Burrows and Holland) Jones, 1895, for the band round the body of the test appears to be very slightly concave.

The edges of the band are just raised above the surface, and the space between is roughened. It will be noticed, by reference to the *Challenger* figure, pl. 60, fig. 1, that there is a ridge, or minor keel, between the side keel and the central one, and I take my specimens to be in the same condition, only the inner ridge is quite close to the central keel. The body of the test is finely pitted all over. The aperture is large, compressed and lipped. In two cases the keel is serrated all round, but it is doubtful if this is natural. The tube is attached. Frequent.—*Locality:* Nos. **42**, **43**.

Lagena Orbignyana Seguenza sp. var. *Walleriana* Wright.

Lagena Orbignyana sp. var. *Walleriana* Wright, 1886, *Proc. R. Irish Acad.*, ser. 2, vol. iv., p. 611, and 1891, p. 481, p. 20, fig. 8.

In all the specimens the typical boss is replaced by a ring, which is very slightly raised.—*Locality:* Nos. **2**, **22**, and one or more of the three stations, Nos. **42–44**.

Lagena Orbignyana Seguenza sp. var. *unicostata* Sidebottom.

Lagena Orbignyana Seguenza sp. var. *unicostata* Sidebottom, 1912, *Journ. Q. M. C.*, p. 417, pl. 19, fig. 22.

The single costa in this case runs the whole length of the body of the test. Very rare.—*Locality:* Nos. **18**, **22**.

Lagena Orbignyana Seguenza sp. var. *pulchella* Brady (Pl. 17, fig. 13).

Lagena pulchella Brady, 1866, *Rept. Brit. Assoc.* (Nottingham), p. 70.

Lagena pulchella Brady, *Annals and Mag. Nat. Hist.*, 1870, p. 294, pl. 12, fig. 1.

The largest specimens are very similar to *L. Orbignyana* var. *variabilis* Wright, 1891, pl. 20, fig. 9, but the costae are irregular and cover the whole of the body of the test; sometimes there is a fine ridge showing between the main keel and the side keels. Very rare.—*Locality:* Uncertain.

A smaller set is frequent, with few and irregular costae. The side keels amount to little more than slight ridges.—*Locality:* No. **44**.

A few very small examples are also present.

Pl. 17, fig. 13. This solitary example has the costae well raised, and as they are irregular I have placed it under the above heading. The side keels are only just apparent.—*Locality:* No. **44.**

† Pl. 19, fig. 24. Very rare. See remarks † p. 418.—*Locality:* Nos. **1, 38.**

Lagena Orbignyana Seguenza sp. var. *clathrata* Brady (Pl. 17, fig. 14).

Lagena clathrata Brady, 1884, p. 485, pl. 60, fig. 4.

The type-form occurs, but is always rare, except at No. **43,** where eleven were found.—*Locality:* Nos. **17, 18, 24, 29, 35, 37, 38, 43, 44.**

A few very small specimens are present, but they are not typical. Others are minute, with numerous fine costae either straight or curved, these latter resembling *L. variabilis*, as Mr. Millett remarks in his Malay Report, 1901, p. 628.

Pl. 17, fig. 14. I think this may be brought under the above heading. The test is compressed and has three keels; these stand out more than the three costae which run down each face of the test.—*Locality:* Nos. **8, 10–14;** frequent at No. **8.**

Lagena Orbignyana Seguenza sp. var. *variabilis* Wright.

Lagena Orbignyana sp. var. *variabilis* Wright, 1890, p. 482, pl. 20, fig. 9.

Except that the side keels are not so well developed, and the striae are very numerous, the specimens are fairly typical. In several instances the striae are inclined to cover the body of the test, and in others they are either absent or scarcely perceptible.—*Locality:* **2, 5–7, 10–14, 16–18, 24, 29, 34, 35.**

Lagena Orbignyana Seguenza sp. var. (Pl. 17, fig. 15).

The test is only slightly compressed; the main keel, which starts at the orifice, splits as it approaches the body of the test. Very fine bars cross the space thus formed. Between the cross-bars is a well-marked circular depression. Besides the side keels there are two semicircular costae, one of these on each face of the test. At the base is an irregular circular projection to which the keels are attached. The wall of this projection is thin.

Only two specimens were found, each of them badly fractured. Both have been utilised in preparing the illustration, which must be considered as a drawing of a restored specimen.—*Locality:* Uncertain.

Lagena bicarinata Terquem sp. (Pl. 17, figs. 16, 17).

Fissurina bicarinata Terquem, 1882, p. 31, pl. 1 (9), fig. 24.

The type-form does not appear to be present.

Pl. 17, fig. 16. The tests are in a very opaque condition.—*Locality:* Nos. **23, 24, 33, 34, 40**.

Pl. 17, fig. 17. There are two or more spines at the base. Eleven specimens are in good condition.—*Locality:* Nos. **2–3**.

† Pl. 19, fig. 27. See remarks † p. 419.—*Locality:* Nos. **2–4**.

A few also occur, very similar to these, except that the body of the test is more circular in outline.—*Locality:* Uncertain.

Lagena bicarinata Terquem sp. var. (Pl. 17, fig. 18).

Test bicarinate. The faces of the test are slightly convex, and the two keels slope towards their edges, the effect being that the test appears to have a boss on either face. Orifice much compressed and composed of a row of pores. A solitary specimen.—*Locality:* No. **37**.

Lagena bicarinata Terquem sp. var. (Pl. 17, fig. 19).

Test bicarinate and apiculate, with a row of very short tubular projections running round the edge of the test between the keels. The test becomes more compressed as the orifice is approached. Two examples only occur. The neck appears to be broken off in both cases.—*Locality:* No. **43**.

Lagena bicarinata Terquem sp. var. (Pl. 17, fig. 20).

Test bicarinate, the keels generally dying away as they approach the orifice, which is composed of a series of fine pores. I cannot say if the fine bands, which adorn each face of the test, are raised or not. Bands of different nature and length are found on other species besides *L. fasciata*, so I prefer to place this form under *L. bicarinata*, instead of treating it as *L. fasciata* in the bicarinate condition.—*Locality:* Nos. **1–10, 13, 15, 16**.

Lagena auriculata Brady (Pl. 17, figs. 21, 22, and pl. 18, fig. 1).

Lagena auriculata Brady, 1881, *Quart. Journ. Micr. Sci.*, vol. 21 (N.S.), p. 61.
Lagena auriculata Brady, 1884, p. 487, pl. 60, figs. 29, 31, 33.

This is largely represented, especially in its variations; intermediate forms occur which it would be interesting to figure.

Pl. 17, fig. 21. In this solitary specimen the wing has divided at a point a little above the body of the shell.—*Locality:* No. **29** or No. **39**.

Pl. 17, fig. 22. A neat form which appears to be strongly built. The shell is moderately compressed. The entosolenian tube, when present, is very short and straight. The orifice is crowned with a boss, and the loops at the base are feebly represented. Nine specimens occur.—*Locality:* Nos. **2, 10**.

Pl. 18, fig. 1. A stoutly-built form. The test is subcarinate, and the orifice situated in a depression. The two loops at the base are feebly developed. Very rare.—*Locality:* Uncertain, but after station No. **23**.

† Pl. 20, fig. 4. A few examples resemble this variation, the keel being continuous round the edge of the test.—*Locality:* Nos. **23, 24, 26, 36, 38, 40, 42, 43**.

† Pl. 20, fig. 5. There are twelve examples, closely resembling this figure, but having no small wings at the top of the test.—*Locality:* Nos. **24, 29, 34, 36, 39–41**.

† Pl. 20, figs. 7. 8. A large number are similar to these forms and to *Challenger* Report, pl. 60, fig. 29.—*Locality:* Nos. **2–4, 6–12, 17–24, 26–29, 33–35, 38–43**.

† Pl. 20, figs. 9, 10. Some forms present lie more or less between the two figures given at this reference.—*Locality:* Nos. **2–6, 6–11, 17, 18, 21, 22**.

† Pl. 20, figs. 11, 12. Only two or three specimens are near † fig. 11; all the rest, and there are over eighty, are like † fig. 12. —*Locality:* Nos. **1–11, 22, 23, 33, 34, 37, 39**. Most of them were found at Nos. **1–11**.

† Pl. 20, fig. 13. Nine examples occur, and one is in the trifacial condition.—*Locality:* Nos. **1, 38, 42–44**; the trifacial specimen at No. **43**.

† Pl. 20, fig. 14. Eight specimens found.—*Locality:* Nos. **1–4**.

Lagena auriculata Brady var. nov. *caudata* (Pl. 18, figs. 2, 3).

Test compressed, the lower part of the body faintly striated. A single long spine, probably always bent more or less to one side, projects at the base. Orifice situated at the end of a long neck. In fig. 2 the basal spine is partly broken off.

The faint striation seems to indicate an affinity with *L. auriculata* var. *costata* Brady, but in order to avoid giving subvarietal names, I have treated it as a variation of *L. auriculata*.—*Locality :* No. **2**.

Lagena auriculata Brady var. nov. *circumcincta* (Pl. 18, fig. 4).

Test compressed, subcarinate, except at the lower edge and base, where the keel is well developed. A few costae run across each face of the test. Orifice oval. Entosolenian tube long and curved. Four specimens occur. There are six tests on the square, but two do not belong to the same variety.—*Locality :* No. **43**, and one of the following stations: Nos. **38, 42, 44,** but which one is doubtful.

Lagena auriculata Brady var. nov. *clypeata* (Pl. 18, fig. 5).

Test compressed, carinate. Orifice oval. Two raised oval rings (sometimes slightly irregular) on each face of the shell. The loops at the base small. Entosolenian tube long and curved. It is easy to miss noticing the loops. The tests vary a little from one another in outline. The keel is not quite so wide as indicated in the drawing.

About twenty specimens are arranged on the same square as a number of *L. Orbignyana* sp. var. *Walleriana* Wright, for which they may have been temporarily mistaken.—*Locality :* The majority must have been found either at Nos. **42** or **43**, or both.

Lagena auriculata Brady var. Sidebottom (Pl. 18, fig. 6).

Lagena auriculata Brady var. Sidebottom, 1912, *Journ. Q. M. C.*, p. 421, pl. 20, figs. 15–18.

Pl. 18, fig. 6 and † pl. 20, fig. 15. I have figured one of average size. There are often a few spines at the base.—*Locality :* Nos. **4, 23, 24, 38–44.**

A few elongate examples occur.—*Locality :* Nos. **2. 3**.

Several approach ✢ pl. 20, fig. 18.—*Locality :* Uncertain.

✢ Pl. 20, fig. 17. A number are near this form, and mixed with them are several identical with Mr. Millett's Malay Report, pl. 14, fig. 15.—*Locality :* Nos. **1-4.**

A few elongate specimens occur, the body being striated, or wrinkled, as indicated in the figure.—*Locality :* Nos. **8**, **9**, **11**.

Lagena auriculata Brady var. *arcuata* Sidebottom.

Lagena auriculata Brady var. *arcuata* Sidebottom, 1912, *Journ. Q. M. C.*, p. 421, pl. 20, figs. 19, 20.

✢ Pl. 20, fig. 19. The specimens differ from the figure, as the arches radiate from the base.—*Locality :* Nos. **4-7**, **9**, **10.**

Lagena auriculata Brady var. *costata* Brady.

Lagena auriculata Brady var. *costata* (Brady) Sidebottom, 1912, *Journ. Q. M. C.*, p. 422, pl. 20, figs. 21, 22.

✢ Pl. 20, fig. 22. See remarks, ✢ p. 422.—*Locality :* Nos. **23**, **24**, **29**, **33**, **39**, **42.**

Lagena auriculata Brady var. *duplicata* Sidebottom (Pl. 18, figs. 7, 8).

Lagena auriculata Brady var. *duplicata* Sidebottom, 1912, *Journ. Q. M. C.*, p. 422, pl. 20, fig. 23.

Pl. 18, fig. 7. The loops in this case extend from the base almost to the neck. At the first glance, I took the specimens to be *L. Orbignyana*, as in some of the specimens débris or shell-growth partially covered the loops, the inner sides of which are quite close to the keel ; a closer examination of other examples, which are free from débris, show the loops to be complete. The tests, of which there are ten, are large.—*Locality :* No. **42**.

Note.—The above might, with equal propriety, be treated as a carinate form of *L. alveolata* var. *separans* Sidebottom, 1912, ✢ pl. 21, fig. 4.

Pl. 18, fig. 8. This differs from ✢ Pl. 20, fig. 23, chiefly in the

absence of the carina. Very rare.—*Locality:* Nos. **29**, **34**, **39**. Two or three were found at other stations besides those indicated.

Note.—Several examples occur almost identical with the above; the only difference being that the loops merge together as in *L. alveolata*, and so must be treated as such.

† Pl. 20, fig. 23. One specimen. *Locality:* Uncertain.

Lagena fimbriata Brady (Pl. 18, fig. 9).

Lagena fimbriata Brady, *Quart. Journ. Micr. Sci.*, vol. 21 (N.S.), 1881, p. 61.
Lagena fimbriata Brady, 1884, p. 486, pl. 60, figs. 26-28.

Two specimens occur similar to the *Challenger* Report, pl. 60, fig. 28.—*Locality:* Uncertain.

Pl. 18, fig. 9. This is a neat, small, compactly built variety, and the fimbriated portion does not appear liable to get fractured. The tube is curled upon itself. The test is moderately compressed, and the opening at the base is very narrow. This variety must not be confused with pl. 20, fig. 28.—*Locality:* Nos. **31**, **43**, **44**; frequent at No. **44**.

† Pl. 20, fig. 24. Two examples only occur.—*Locality:* No. **31**.

† Pl. 20, fig. 25. Eight specimens.—*Locality:* One or more of the following stations: Nos. **5**, **6**, **22**.

† Pl. 20, fig. 26. Four very fine examples occur.—*Locality:* Nos. **4**, **6**, **8**, **10**.

Three specimens, with the base more pointed and the opening more contracted, are also on the slide.—*Locality:* Nos. **7**, **10**, **12**.

Lagena fimbriata Brady var. nov. *duplicata* (Pl. 18, fig. 10).

Test compressed, ovate. There are two narrow loops, side by side, across the width of the test at its base. Tube curled on itself. I think the walls of the loops are tubulated, but cannot be quite certain about it. A solitary specimen.—*Locality:* Uncertain.

There is another test which has the orifice wider, and the tube short and straight. The loops are in the same position, but so feebly represented that it is doubtful whether it belongs to the above variety.

Lagena fimbriata Brady var. *occlusa* Sidebottom.

Lagena fimbriata Brady var. *occlusa* Sidebottom, 1912, *Journ. Q. M. C.*, p. 423, Pl. 20, figs. 27, 28.

+ Pl. 20, fig. 27. Common. Most of the specimens have the opening at the base more open than in the illustration. See remarks, + p. 423.—*Locality:* Nos. **1–4, 6–13, 15, 17, 19, 22, 24, 25, 29, 31, 33–35, 37–42.**

Lagena alveolata Brady (Pl. 18, figs. 11, 12).

Lagena alveolata Brady, 1884, p. 487, pl. 60, figs. 30, 32.

Pl. 18, fig. 11. The tests are large and strongly built. All are in the apiculate condition. The dotted line indicates the boundary of the chamber, thus showing the thickness of the wall. Orifice oval. Twelve examples occur.—*Locality:* Nos. **1, 5.**

Pl. 18, fig. 12. There are a large number present. The tests are fairly well compressed. The chief peculiarity is that, though the entosolenian tube is straight, the orifice opens out well below the median line. The part above the orifice is sharpened. The loops at the base are small, and their outer edges do not project nearly so far as does the central carina.—*Locality:* Nos. **1–15, 17–20.**

+ Pl. 21, fig. 1. Unfortunately the specimens are mixed with another species, so that the stations at which they were found are uncertain. There are a fair number on the slide.

+ Pl. 21, fig. 2. Good examples are present.—*Locality:* Nos. **1, 3–5, 7, 10, 16, 17.**

Lagena alveolata Brady var. *carinata* Sidebottom.

Lagena alveolata Brady var. *carinata* Sidebottom, 1912, *Journ. Q. M. C.*, p. 424, pl. 21, fig. 3.

This form is very rare in this collection.—*Locality:* Nos. **24, 39, 40.**

Lagena alveolata Brady var. *substriata* Brady.

Lagena alveolata var. *substriata* Brady, 1844, p. 488, pl. 6, fig. 34.

A single specimen. It is not quite typical, the neck of the test being more produced than in the *Challenger* figure.—*Locality:* No. **39.**

Lagena alveolata Brady var. *separans* Sidebottom.

Lagena alveolata Brady var. *separans* Sidebottom, 1912, *Journ. Q. M. C.*, p. 425, pl. 21, fig. 5.

Locality: Nos. **1–3, 5, 6, 17–20, 23–25, 34, 38.**

Lagena clypeato-marginata Rymer-Jones var.

Lagena clypeato-marginata Rymer-Jones var. Sidebottom, 1912, *Journ. Q. M. C.*, p. 425, pl. 21, fig. 6.

Several examples occur.—*Locality:* Uncertain.

Lagena magnifica Sidebottom.

Lagena magnifica Sidebottom, 1912, *Journ. Q. M. C.*, p. 425, pl. 21, fig. 8.

A few of the specimens are in the transparent condition.—*Locality:* Nos. **1–5, 7.**

Lagena Elcockiana Millett.

Lagena Elcockiana Millett, 1901, p. 621, pl. 14, figs. 5, 6.
Lagena Elcockiana (Millett) Sidebottom, 1912, *Journ. Q. M. C.*, p. 426, pl. 21, fig. 9.

A single specimen.—*Locality:* Uncertain.

Lagena galeaformis Sidebottom.

Lagena galeaformis Sidebottom, 1912, *Journ. Q. M. C.*, p. 426, pl. 21, figs. 11, 12.

† Pl. 21, fig. 12. Only the trifacial form appears to be represented in these gatherings.—*Locality:* Nos. **1–3.**

There are a few tests which may, or may not, be the bifacial form of this species. I have included them under † pl. 20, fig. 17, on page 421. They are not so stout as this figure represents, and the side keels are entire as far as the tubular process.

Lagena protea Chaster.

Lagena protea Chaster, 1892, p. 62, pl. 1, fig. 14.

See remarks, † p. 427.—*Locality:* Nos. **2, 10, 17, 19, 22, 23, 25, 38, 39, 43, 44.**

Lagena invaginata sp. nov. (Pl. 18, fig. 13).

Test slightly carinate; oral end protruding and arched; orifice a narrow slit, perhaps barred. The front highly convex; the back flat, with a large concave recess at the base. The entosolenian tube long and bent to one side. Twenty-one examples occur.—*Locality:* Nos. **38, 41, 42**; chiefly at No. **42**.

Lagena reniformis sp. nov. (Pl. 18, fig. 14).

The test reminds one of a kidney bean in shape; the orifice is situated on one side of the median line. The entosolenian tube is long and attached. A few of the specimens are not nearly so wide in relation to the height as the one figured.—*Locality:* About sixteen at No. 44. It occurs also at several other stations.

Lagena reniformis sp. nov. var. (Pl. 18, fig. 15).

I am treating this as a variation of the above. I believe the orifice is composed of a series of pores, at any rate it is exceedingly narrow. There are two other tests along with it, in which the width is about equal to the height, but I think they belong to the same variety.—*Locality:* Uncertain.

Lagena reniformis sp. nov. var. *spinigera* (Pl. 18, fig. 16).

The test is compressed, and the two spines, one on either side, project upwards. The orifice is slightly sunk, and the tube is long and attached, reaching almost round the shell. Two specimens only found.—*Locality:* Nos. **29, 44**.

Lagena sp. incert. (Pl. 18, fig. 17).

Probably this is only *L. marginata* in a contorted condition. The test is carinate, compressed and twisted. Two occur.—*Locality:* Both at No. **15**; or one at No. **1** and the other at No. **15**.

Lagena lagenoides Williamson sp. var. (Pl. 18, fig. 18).

The test is elongate, not much compressed, and bicarinate. Aperture fissurine. The keels, which only project slightly, are tubulated.

I take this to be an elongate variety of *L. lagenoides*, Williamson sp., pl. 17, fig. 1. Three occur.—*Locality:* No. **40**.

Lagena staphyllearia Schwager sp. var. (Pl. 18, fig. 19).

Test compressed (lower part angular in outline) with five very small protuberances arranged, as shown in the drawing, on the edge of the shell. The entosolenian tube starts straight and then bends towards the back of the test. Only four occur, and they vary a little in outline.—*Locality :* Nos. **3, 11.**

Lagena sp. incert. (Pl. 18, fig. 21).

I have only made an outline drawing of this form, because I am not sure what its natural condition may be. The test is compressed, and nearly all the examples are covered with shell-growth, which has a sugary appearance. The colour is a light cream. In those that are partially free from this incrustation, the test appears to be more or less in a hispid condition. The carina, starting at the orifice, often ends abruptly, as shown in the illustration, but sometimes it gradually diminishes until it is lost about half-way down the test. Two or more spines adorn the base. It may be a compressed form of *L. hispida.* —*Locality :* Nos. **23, 29, 39, 40, 41.**

Lagena sp. incert. (Pl. 18, fig. 22).

I am puzzled with this form, not knowing whether to treat it as *L. marginata* in which the keel has split, thus forming two long loops, one on either side of the test; or, as *L. auriculata* in which the loops extend almost to the neck. It will be noticed that the loops are quite separate at the base. Three occur. The specimens are mixed with those of another form.—*Locality :* One must have been found at No. **43** or No. **44.**

? **Lagena** sp. (Pl. 18, figs. 23, 24).

I believe this to be a foraminifer, but it is very doubtful if it be a Lagena. There was a small test, on the same square, which had every appearance of being the initial chamber of the same species. Unfortunately, in using a high-power lens for examination, I accidentally crushed the specimen; but I had previously made an outline drawing of it, see pl. 18, fig. 24.

The large test, pl. 18, fig. 23, is not compressed. The orifice is a rosette in form, and the upper part of the test is covered with a raised irregular mesh. Rows of tubular projections run at

intervals across the test. It being a solitary example I do not care to make a section of it, but probably it would reveal a series of chambers. As Mr. Thornhill has placed it among the Lagena, and it is such an interesting object, I cannot resist the opportunity of figuring it. It is opaque, but the single-chambered specimen was quite transparent.—*Locality:* No. **42.**

Lagena maculata sp. nov. (Pl. 18, fig. 25).

I was unable, for various reasons, to make out the nature of this interesting species, so submitted the test to Mr. Earland, and he has kindly sent me the following description of it:

"The shell appears to consist of two, probably three layers. An inner test which is covered with a raised hexagonal outline pattern, like network over a ball, and this in turn is covered with an extremely thin outer test. This latter may be merely chitinous or membranous; it is sufficiently thin to show diffraction spectra. Where this outer layer is stretched over the raised pattern it is depressed in a rounded fashion, as though it had been pressed down with the tip of the finger into the hexagonal cavity beneath."

A solitary example. It belongs to the *Waterwitch* set of Lagenae. Test not compressed.

Locality: No. **13.** Station 238, Lat. 12°44′ S., Long. 179°09′ W. (1,050 fms.).

Lagena marginata Walker and Boys var. *ventricosa* Silvestri.

Lagena ventricosa Silvestri, 1903–1904, *Accad. Reale delle Scienze di Torino*, p. 10, figs. 6 *a–e*.

This seems to me simply a stout form of *L. marginata*. There are eleven large specimens, but the carina is carried a little farther up the test. Three of the tests are nearly round in section. Examples moderately compressed, with orifice of the same character, I have placed with *L. marginata*.—*Locality:* Nos. **5, 15.**

[Mr. Henry Sidebottom has decided to make a type-slide of the species described in his two papers as an index to the collection of Lagenae. The collection will then be presented to the British Museum (Natural History), South Kensington, under the title, "The Thornhill Collection of Lagenae (South-West Pacific)."

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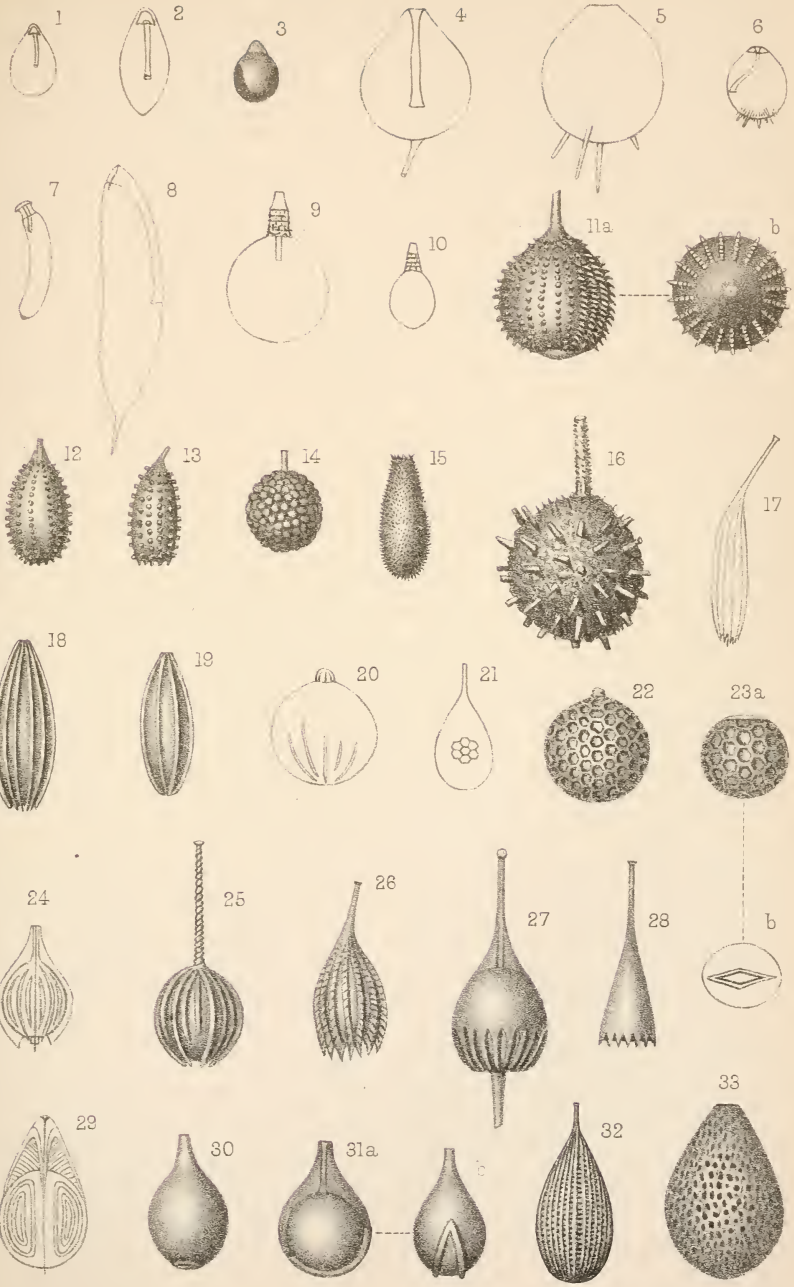
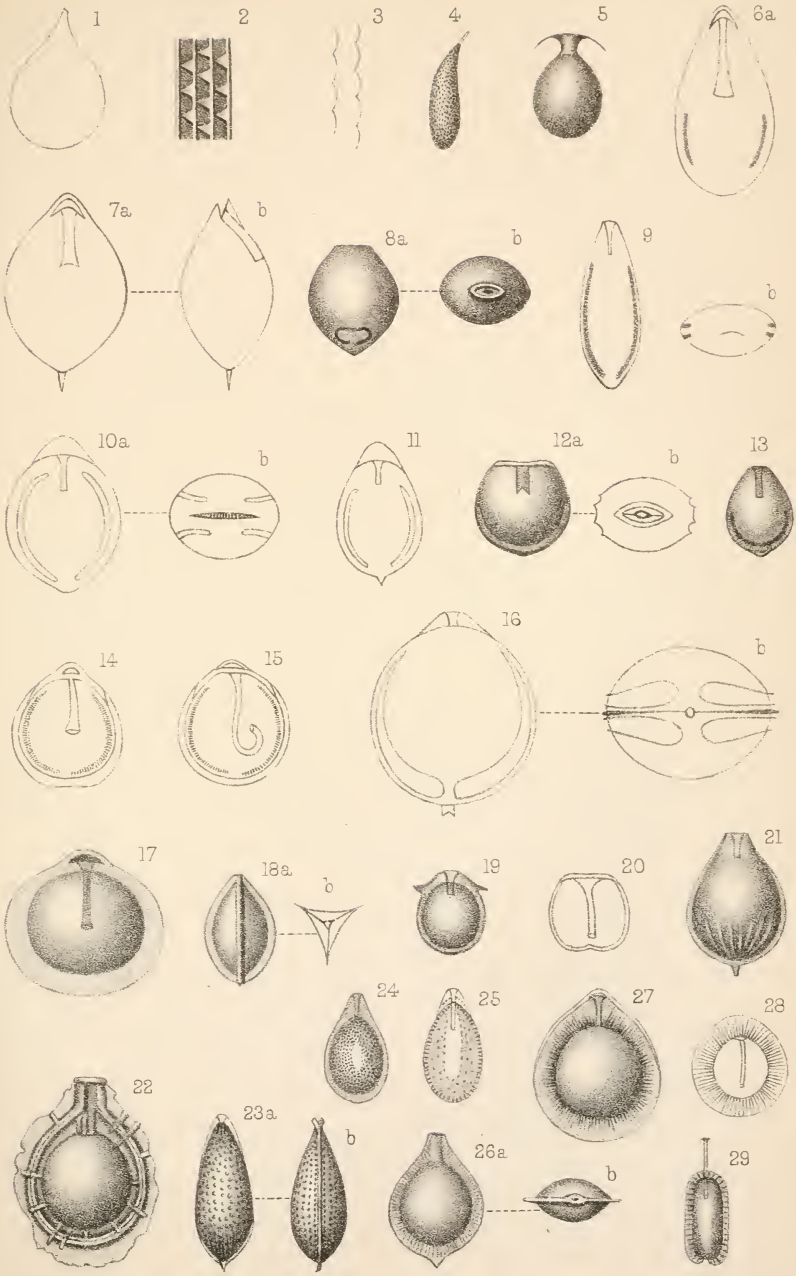


H. Sidebottom del. ad nat. West, Newman lith.

Lagenae of the South West Pacific Ocean.



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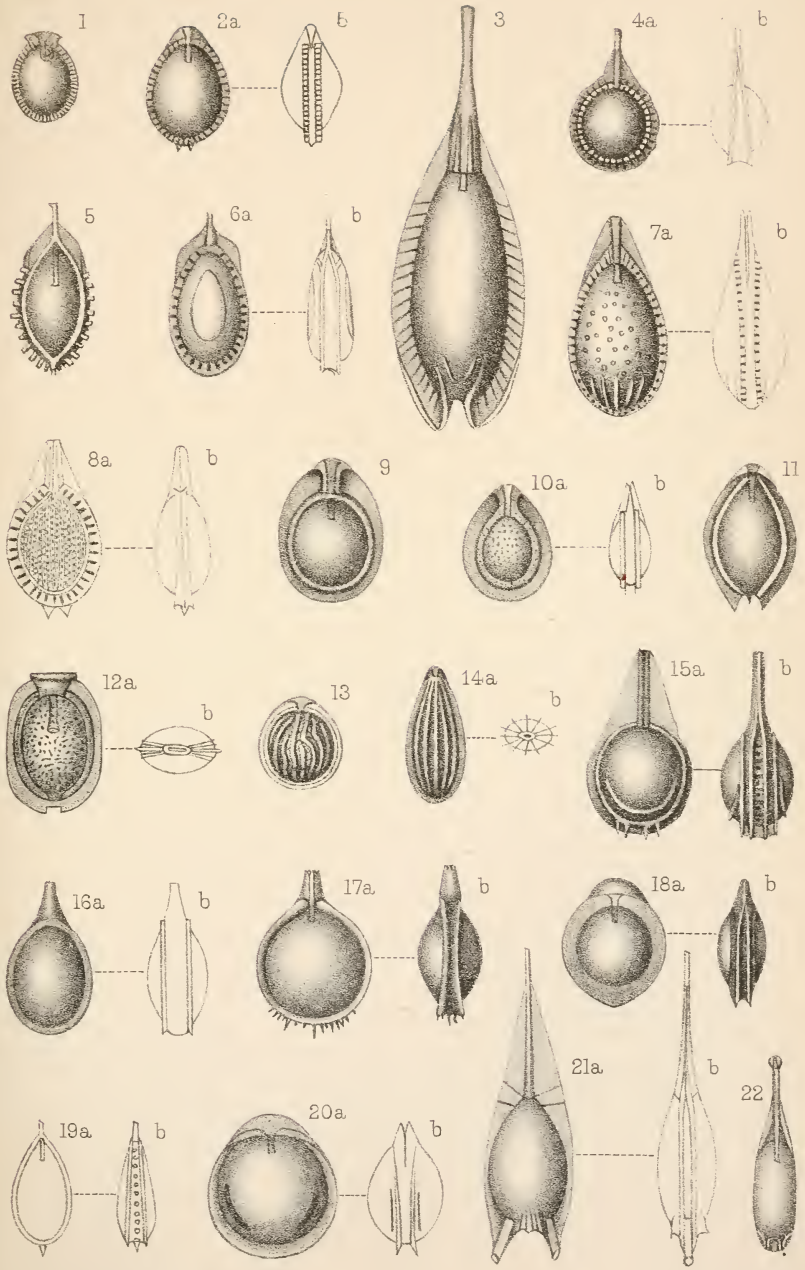

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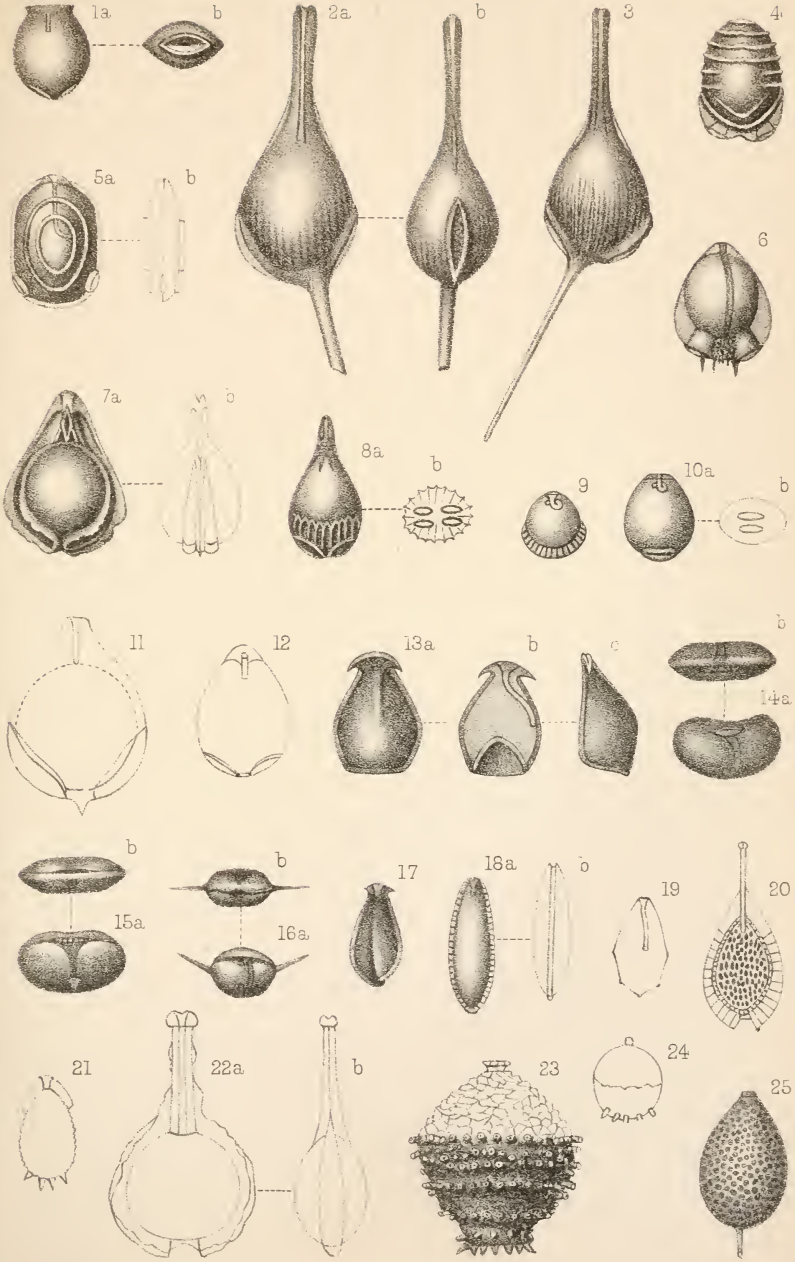


H. Sidebottom del. ad nat. West, Newman lith.

Lagenae of the South West Pacific Ocean.

GASTROTRICHA.

By James Murray, F.R.S.E.

Communicated by D. J. Scourfield.

(*Read October 28th*, 1913.)

Plate 19.

INTRODUCTION.

I have been reluctant to attempt an introduction to the study of the Gastrotricha, since my knowledge of the group is by no means profound, and such as it is has been only recently acquired. It is a group which has now reached such dimensions that it is desirable there should be in the English language some sort of synopsis of our present knowledge, and as there appears to be no one else in the field to supply this want, I shall here do the best I can.

The main part of this paper is an annotated bibliography, which I hope will save students much of the trouble I have had. It is difficult to hit a just mean between giving too much and too little. If too comprehensive and not annotated, a bibliography rather hinders than helps by making the mass of works to be consulted seem too great. A work is judged by its title to be one that must be consulted, and after much labour is found to be of no importance. I had a long search for a new genus and species, *Gastrochaeta ciliata*, described by Grimm, before I found that the name occurred in a mere list, in Russian, without a figure, and that in a footnote all the comparison made was with species of *Desmoscolex*, which belongs to a quite different group of worms (25).

If the bibliography is too condensed the student is always liable to suspect that a work omitted from it has not come to the knowledge of the compiler. Such things frequently happen. I have here tried to keep a proper balance. All important

general, biological and systematic works known to me are included, as well as any really important faunistic studies. Every work is given in which new species, or supposed new species, or groups of higher value are described. The systematic student wants these principally. There are omitted all merely popular accounts, all trifling faunistic studies (records usually of doubtful value), all references in textbooks of zoology which contain nothing fresh, pronouncements on systematic position, which are mostly only opinions not backed by personal knowledge of the animals.

Monographists and close students of distribution will require more than this bibliography contains, but they will be able to get it for themselves.

It is unfortunate that the Gastrotricha, which include those old familiar friends of the students of pond life—*Chaetonotus larus* and *Ichthydium podura*—have no popular name. Gosse's proposed name of "hairy-backed animalcules" is entirely unsuitable, since some of the genera are not hairy-backed (*Ichthydium*, *Lepidoderma*). I confess I am unable to suggest any appropriate name. The name suggested by the scientific term for the whole group, which embodies almost the only character which they all possess, is unsuitable for popular use.

The Gastrotricha are not animals which can be named offhand. The days when we found *Chaetonotus larus* and *Ichthydium podura*, occasionally varied by *C. maximus*, on all our pond-life excursions are over. There are a host of Chaetonoti which have contributed to the records of *C. larus*. These species are all alike to a casual glance, but are distinguished by minute characters—the possession of small branches by certain of the bristles, the form of the minute scales which bear the bristles, etc. Some of these are so delicate that a high power and an oil-immersion lens would be needed for their certain determination. This is impossible to apply to a living and lively *Chaetonotus*, and as to killing the creature merely in order to find out its name, well—a philosophic naturalist might prefer to remain ignorant. To destroy this marvellous little living gem simply to know how to label it; is it worth while?

Now we students of microscopic life cannot pretend to be squeamish; we have learned to kill lightly; every time we clean a cover-glass we annihilate a world. But when it comes to

deliberately ending the individual life which we have before our eyes, intelligent, and surely innocent, I confess that, old and hardened as I am at the game, I feel guilty of—murder. My ideal is that realised by Mr. Bryce, with his "zoo" of Rotifera, all kept alive in cells, visited again and again for weeks and months, till they become old familiar friends, each known by sight and name; where a death in the family is regretted, and the beasties, in fact, reach a ripeness of old age which must be rare under natural conditions.

I wish to thank Mr. Rousselet and Mr. Bryce for the assistance they have given me in preparing this paper, by lending me specimens and books, and Mr. Harring for bibliographical references and extracts from works which I had not seen.

Form and Structure.

All Gastrotricha are built on a very uniform plan. Most of them have a roundish, often 3- or 5-lobed head, a more or less distinct neck and a slightly expanded body, diminishing posteriorly to a usually forked, but sometimes undivided extremity (tail or foot). The principal external features are: the tubular mouth, certain sensory hairs on the head, various forms of scales and hairs clothing the dorsal surface. The ventral surface is traversed for its whole length by two bands of vibratile cilia, by which the creatures can creep in the manner of an *Adineta*, and sometimes even, apparently, swim. A few possess clear bodies which have been supposed to be eyes.

Of the internal structure I shall say little, as I have given it little study, and I can only quote from authors who have studied it. The animals are on about the same plane as the Rotifera for complexity, but they look much simpler—fewer organs are readily visible. A casual examination shows only a thick skin and the body cavity, through which passes the simple alimentary canal; the slender oesophagus passing through an oblong muscular pharynx; the expanded stomach (or intestine) occupying most of the body cavity. There is a small intestine, from which the anus opens at the base of the furca, on the dorsal side.

Several naturalists have detected a water-vascular system somewhat like that of the Rotifera, but according to Zelinka it differs in many points. The canals are much convoluted,

and possess only one vibrating cell corresponding to the series of flame-cells of Rotifera; there is no contractile vesicle, and the canals open independently on the ventral side and have no connection with the intestine.

While the eggs are frequently conspicuous, and their development may be conveniently studied, the sexual system is little known. Zelinka distinguishes paired ovaries. If the supposed male organs are such the Gastrotricha are hermaphrodite.

Zelinka recognises in the alimentary canal the following parts: mouth, oesophagus, stomach, intestine with rectum and anus.

There is a well-developed muscular system, and the brain and nervous system are similar to those of the Rotifera.

Haunts and Habits.

The Gastrotricha are found mainly in ponds, oftenest among the bottom sediment or vegetation. They rarely occur on mosses, except the permanently moist aquatic kinds. A few (at least one species, *C. marinus*) live in the sea.

They are much less common, even in ponds, than the Rotifers and Water-bears. You cannot go out to collect assured of getting some—you must trust to casual occurrences when studying other things.

There are no special methods of collecting them. They will occur among your Rotifers, but not if you collect in clear, open water. Perhaps the likeliest means to obtain some is to wash aquatic weeds—*Myriophyllum*, *Fontinalis*, *Lemna*, etc.

If you wish to preserve them it can easily be done. As they are not contractile, they can be killed without previously narcotising by osmic acid, when they retain the natural shape. They can be mounted in fluid cells by Rousselet's method, but formalin of the strength used for Rotifers is not a suitable medium, as it produces subsequent distortion. Some better medium has yet to be found.

They appear to have only one habit, that of eating. They are always in motion, some slowly, some quickly, and always seem to be nosing for food. Yet they are not greedy eaters, but pick daintily here and there. As they creep along over the weeds they give the impression of active intelligence proportioned to their needs.

Historical Sketch.

As a history would be little more than the bibliography arranged chronologically, it need not take up much space.

So far as my knowledge goes, the first notice of an animal of this order is by Joblot (**32**) 1718, who figures (Plate 10, fig. 22) his "poisson à la tête en trèfle," which is the animal now known as *Ichthydium*.

Corti 1774 (**10**) speaks of an "animaluzzo molle," and figures it, which Ehrenberg thinks may be a *Chaetonotus*.

Eichhorn 1781 (**20**) figures (Plate 2, fig. R) what may have been a *Chaetonotus*.

These were the pioneers, who bestowed no binomial designations, but, before either Eichhorn or Corti, Müller had in 1773 (**42**) given three such names, the first, *Cercaria podura*, still persisting as *Ichthydium podura*.

Many of the pre-Ehrenbergians bestowed various names on Gastrotrichs, usually only in attempts to classify, not describing supposed new species: Schrank 1776 (**53**) *Brachionus pilosus*; Lamarck 1815 (**34**) *Furcocerca*; Bory 1824 (**3**) *Leucophra*, 1826 (**4**) *Diceratella*; Ehrenberg's first attempt, Hemprich and Ehrenberg 1828 (**29**) was *Diurella podura* (= *Ichthydium*).

Ehrenberg did not notably advance the knowledge of this order, but he described two new species besides others, which are not now recognised as Gastrotrichs.

After Ehrenberg came a rather barren period leading on to quite modern times: Dujardin 1841 (**16**), Gosse 1851 (**23**) and 1864 (**24**), Schultze 1853 (**55**), Schmarda 1861 (**52**), Metchnikoff 1865 (**41**), Tatem 1867 (**61**). The only works of any importance in this period are Gosse's and Metchnikoff's.

Modern times may be said to begin with Daday in 1882 (**11**), and the principal workers have been Daday 1897 (**12**), 1905 (**14**), 1910 (**15**); Collin 1897 (**8**), 1912 (**9**); Stokes 1887 (**57**) (**59**); Zelinka 1889 (**71**); Voigt 1904 (**68**); Lauterborn 1893 (**35**); Grünspan 1908 (**26**); Marcolengo (**40**) (**72**).

Classification.

The classification of the Gastrotricha is in an unsatisfactory condition. They are difficult animals to classify. I sympathise with the efforts authors have made to introduce order into the

group, and will not attempt to modify the generic arrangement, beyond shifting about some of the species. I am not qualified to deal with the question, but as some little assistance to students I shall point out some apparent shortcomings of the prevailing classification.

The three fork-tailed genera, *Ichthydium*, *Chaetonotus* and *Lepidoderma*, are separated on very slight characters, as Stokes (57) recognised in "lumping" them all together. *Ichthydium* has neither plates nor dorsal bristles; *Lepidoderma* has scales, but is supposed to have no bristles; *Chaetonotus* has bristles, and may have scales. So if an *Ichthydium* or a *Lepidoderma* possesses any dorsal bristles it becomes a *Chaetonotus*. How many bristles are necessary? Some so-called *Lepidoderma* have a very few bristles. *L. loricatus*, Stokes, has no bristles, while a variety has four near the tail.

Authors have made the matter worse by entirely disregarding the generic definitions, even those made by themselves. Thus Zelinka's *Lepidoderma* was instituted first to contain Dujardin's *C. squammatus*, which was described in these terms, "Revêtu en dessus de poils courts, élargis en manière d'écailles pointues régulièrement imbriquées," and which is thus a true *Chaetonotus*, following Zelinka's own definition.

The possession or not of scaly armour is surely itself more important than the presence or not of bristles on the scales, but the character has not been used in classification quite rightly, for the scales are after all only the enlarged bases of the hairs, and there is every gradation from a slightly enlarged insertion to large imbricated scales.

Authors have further confused matters by professing to identify as the species of the earlier authors animals which are quite different from their descriptions and figures. This is pernicious, as the practice nullifies the meaning of language, however precisely used. It may be admitted that the descriptions of Müller and Ehrenberg are insufficient to distinguish their species from the numerous similar species now recognised. But the species must either be dropped as "insufficiently described," or, if we profess to recognise them, it must be in animals possessing at least the characters ascribed to them by their discoverers.

Ehrenberg has many faults, among which I reckon not least the insufficiency of his descriptions. Frequently these

contain no single distinctive character, and if it were not for his figures their recognition would be impossible. But he was not a slipshod observer, and when he happens to mention a distinctive feature I have no doubt the animal observed possessed it. Thus when he distinguishes *C. maximus* from *C. larus* by its dorsal bristles of equal length, we must give him the credit of supposing that his animal looked like that, unless naturalists agree that no such animal exists—a difficult thing to prove. There are species with the dorsal bristles approximately of equal length, and so Gosse is not justified in identifying as *C. maximus* a species having the posterior bristles much longer.

In the separation into larger groups, sub-orders, or families, the group has been equally unfortunate. The classification by Fräulein Grünspan (**26**) recognises three sub-orders :

Suborder I. *Euichthydina*, having a forked tail.
,, II. *Pseudopodina*, having an apparently forked tail.
,, III. *Apodina*, without a forked tail.

I am unable to grasp the distinction between a forked tail and an apparently forked tail, and the Apodina include one genus (*Stylochaeta*) which has a forked tail ; minute certainly, but is a small tail not a tail ?

Zelinka's (**71**) classification is consistent, but the more puzzling genera were not discovered when he wrote. He recognises two sub-orders, and, I should suppose, three families, though he only names two :

I. Sub-order : *Euichthydina*, having a "furca."
1. Family Ichthydidae, without bristles.
Genera *Ichthydium* and *Lepidoderma*.
2. Family Chaetonotidae, with bristles.
Genera *Chaetonotus* and *Chaetura*.
II. Sub-order : *Apodina*, without a "furca."
Genera *Dasydytes* and *Gossea*.

Collin (**9**) follows Zelinka's classification, naming the family Dasydytidae, which includes all the Apodina, and allocating all the genera described since Zelinka's work to places in the three families.

All this is very unsatisfactory. The anomalies of these systems I have pointed out as exemplified in that of Fräulein Grünspan.

I have no better to offer, so I suggest that we leave classification on broad lines till we know more, and classify in genera only.

These have also been badly handled. Ehrenberg's two genera, *Ichthydium* and *Chaetonotus*, will serve as a beginning of classification till we find something better. The distinction between hairy and smooth is not important, and in many genera of animals both types occur—*e.g. Macrobiotus* among Tardigrada, but among Gastrotricha, if we are to have divisions at all, we must be satisfied with very trivial characters. Müller's *Cercaria podura*, which became the type of *Ichthydium*, was probably a composite diagnosis, as some of his figures show bristles. I have shown the unsatisfactory treatment of his genus *Lepidoderma* by Zelinka, but, if his generic characters were regarded in allotting species to it, it might serve as a temporary artificial genus till we see our way out of the muddle.

Ehrenberg's obsession for symmetry in classification led to many obviously false associations of species, and tyrannised over naturalists till a late period, even as late as 1864 affecting Gosse. It is curious now to regard the genera once included in the Gastrotricha—*Ptygura*, *Glenophora*—and to think that *Sacculus* and *Taphrocampa* were originally described by Gosse as Gastrotrichs.

Key to the Genera.

A. Without a furca.

1. Body with long bristles . . . . *Dasydytes.*
2. Body without long bristles . *Anacanthoderma.*
3. Head with antennae . *Gossea* (*G. antennigera*).

B. Furca minute or obscure.

4. Furca minute, large barbed bristles . *Stylochaeta.*
5. Furca obscure, short . . . . . *Setopus.*
6. Head with antennae . . . *Gossea* (two species).

C. Furca conspicuous, body with bristles.

7. Furca simple, bristles pointed . . *Chaetonotus.*
8. Furca simple, bristles expanded at apex *Aspidiophorus.*
9. Furca twice furcate . . . . . *Chaetura.*

D. Furca conspicuous, body without bristles.

10. Body with scaly armour . . . *Lepidoderma.*
11. Body without scales . . . . *Ichthydium.*

NOTE.—*Anacanthoderma* can hardly be separated from *Dasydytes*, as the only species is described as having some bristles. *Aspidiophorus* is a *Chaetonotus*, having the bristles enlarged at the apex, scarcely a generic distinction, as those having enlarged bases are not considered generically distinct. *Gossea* is usually put in the APODINA, but Daday's two species possess the furca, and Gosse's *antenniger* with its caudal bundles of setae may be said to possess the homologue of the furca. *Setopus primus* is scarcely distinguishable, even as a species, from *Dasydytes bisetosus* Thomp., yet from the possession of a slight medial depression at the posterior end it has technically a furca, and becomes a distinct genus.

LIST OF ALL SPECIES WHICH HAVE BEEN DESCRIBED.

In alphabetical order, and under the original generic names, with critical notes on synonymy and specific values.

1910. *Anacanthoderma punctatum* Marcolongo (**40**).
1902. *Aspidonotus paradoxus* Voigt. (**65**). Now a genus *Aspidiophorus*.
1865. *Cephalidium longisetosum* Met. (**41**). Is a *Dasydytes*.
1773. *Cercaria podura* Müll. (**42**). Now the type of *Ichthydium* Ehr.
1887. *Chaetonotus acanthodes* Stokes (**57**).
1887. *C. acanthophorus* Stokes (**57**).
1903. *C. arquatus* Voigt. (**67**).
1832. *C. breve* Ehr. (**16**).
1889. *C. brevispinosus* Zel. (**71**).
1901. *C. chuni* Voigt. (**64**).
1887. *C. concinnus* Stokes (**57**). Is a *Lepidoderma*.
1910. *C. decemsetosus* Marco. (**40**).
1905. *C. dubius* Dad. (**14**).
1887. *C. enormis* Stokes (**57**).
1905. *C. erinaceus* Dad. (**14**).
1887. *C. formosus* Stokes (**59**).
1864. *C. gracilis* Gosse (**24**).
1905. *C. heterochaetus* Dad. (**14**).
1910. *C. hirsutus* Marco. (**40**).
1865. *C. hystrix* Met. (**41**).

1910. *C. larvides* Marco. (40).
1902. *C. linguaeformis* Voigt. (66).
1867. *C. longicaudatus* Tatem (61). Is an *Ichthydium*.
1887. *C. longispinosus* Stokes (57).
1887. *C. loricatus* Stokes (57). Is a *Lepidoderma*.
1893. *C. macracanthus* Laut. (35). Is probably *C. entzii* (Dad.).
1889. *C. macrochaetus* Zel. (71).
1904. *C. marinus* Giard. (22).
1832. *C. maximus* Ehr. (18).
1910. *C. minimus* Marco. (40).
1908. *C. multispinosus* Grün (26). Is *C. tabulatum* Schm.
1901. *C. nodicaudus* Voigt. (63). Very like *C. entzii* (Dad.).
1910. *C. nodifurca* Marco. (40). Very like *C. entzii* (Dad.).
1887. *C. octonarius* Stokes (57).
1897. *C. ornatus* Dad. (12).
1910. *C. paucisetosus* Marco. (40).
1889. *C. persetosus* Zel. (71).
1909. *C. ploenensis* Voigt. (69).
1905. *C. pusillus* Dad. (14).
1887. *C. rhomboides* Stokes (57). Is probably *C. entzii* (Dad.).
1865. *C. schultzei* Met. (41).
1901. *C. serraticaudus* Voigt. (63).
1889. *C. similis* Zel. (71).
1909. *C. simrothi* Voigt. (69).
1887. *C. spinifer* Stokes (57).
1887. *C. spinulosus* Stokes (57).
1864. *C. slackiae* Gosse (24).
1841. *C. squammatus* Duj. (16).
1902. *C. succinctus* Voigt. (66).
1887. *C. sulcatus* Stokes (57). Is an *Ichthydium*.
1908. *C. tenuis* Grün. (26).
1902. *C. uncinus* Voigt. (66).
1908. *C. zelinkai* Grün. (26).
1865. *Chaetura capricornia* Met. (41).
1913. *C. piscator* Murray. (Described in this paper for first time.)
1851. *Dasydytes antenniger* Gosse (23). Now the genus *Gossea*.
1891. *D. bisetosus* Thomp. (62).
1909. *D. dubius* Voigt. (69).

1909. *D. festinans* Voigt. (69).
1851. *D. goniathrix* Gosse (23).
1909. *D. ornatus* Voigt. (69).
1910. *D. paucisetosus* Marco. (40).
1887. *D. saltitans* Stokes (59).
1901. *D. stylifer* Voigt. (64). Is a *Stylochaeta*.
1893. *D. zelinkai* Laut. (35). Seems to be *D. goniathrix* Gosse.
1886. *Ichthydium bogdanovii* Schim. (51). Is a *Chaetonotus*.
1905. *I. crassum* Dad. (14).
1908. *I. cyclocephalum* Grün. (26).
1882. *I. entzii* Dad. (11). Is a *Chaetonotus*.
1901. *I. forcipatum* Voigt. (64).
1861. *I. jamaicense* Schm. (52). Is a *Chaetonotus*.
1897. *I. macrurum* Collin. (8).
1865. *I. ocellatum* Met. (41).
1861. *I. tabulatum* Schm. (52). Is a *Chaetonotus*.
1908. *I. tergestinum* Grün. (26).
1905. *Gossea fasciculata* Dad. (14).
1905. *G. pauciseta* Dad. (14).
1897. *Lepidoderma biroi* Dad. (12). Is probably *C. entzii* (Dad.).
1905. *L. elongatum* Dad. (14). Is probably *C. entzii* (Dad.).
1910. *L. hystrix* Dad. (15). Is probably *C. entzii* (Dad.).
1890. *Polyarthra fusiformis* Spencer (56). Now genus *Stylochaeta*.
1908. *Setopus primus* Grün. (26). Scarcely differs from *Dasydytes*.
1776. *Trichoda larus* Müll. (43). Now *Chaetonotus larus*.

Identification of Species.

It was my ambition to accompany this paper by a key to all the species hitherto described, so that the student might identify them all, or at least know what characters they were supposed to have. I found the task beyond my powers, for not only are there a number of descriptions which I have been unable to consult, but many of the diagnoses are such that to make use of the characters given in them would be actually misleading.

This is especially true of negative characters. Certain species are described as having the body covered with scales, others as having some or all of the bristles barbed or with supplementary points. It must not be assumed that species not thus characterised do not possess those characters. Both are structures

excessively difficult to see, and the authors of species may have overlooked them.

There is no more definite character for distinguishing species of *Chaetonotus* than the form of the dorsal plates, if one could only see them, but nothing has astonished me more than the utter invisibility of those plates, till some accident, such as finding an empty skin or mutilated specimen, has revealed them.

As I have put some work into the preparation of this key, and do not wish to throw it away, I have made some use of the material by indicating for the genus *Chaetonotus* certain groups of species characterised by the possession of some common feature.

Chaetonotus.

Body covered by Plates or Scales.

C. acanthodes, acanthophorus, arquatus, brevispinosus, chuni, entzii, erinaceus, heterochaetus, hystrix, larus, linguaeformis, macrochaetus, maximus, octonarius, ornatus, persetosus, ploenensis, pusillus, schultzei, serraticaudus, similis, simrothi, spinifer, squammatus, succinctus, tabulatus, tenuis, uncinus, zelinkai.

Stated to have no Plates.

C. enormis, formosus.

Nothing said about Plates.

C. bogdanovii, dubius, gracilis, jamaicense, longispinosus, marinus, slackiae, spinulosus.

With Cephalic Shield.

C. entzii, erinaceus, formosus, maximus, ornatus, persetosus, pusillus, schultzei, tenuis, zelinkai. Not noted for the other species.

Head not Lobed.

C. bogdanovii, dubius, jamaicense, marinus, ornatus, slackiae, tabulatus.

Head Three-lobed.

C. brevispinosus, chuni, erinaceus, formosus, heterochaetus, hystrix, larus, linquaeformis, macrochaetus, pusillus, schultzei, serraticaudus.

Head Five-lobed.

C. acanthophorus, arquatus, enormis, gracilis, longispinosus, maximus, octonarius, persetosus, ploenensis, similis, simrothi, spinulosus, squammatus, succinctus, tenuis, uncinus, zelinkai.

All Bristles with Supplementary Points (Barbs).

C. chuni, erinaceus, hystrix, schultzei, similis, spinifer.

Some Bristles Barbed.

C. acanthophorus, enormis, heterochaetus, longispinosus, macrochaetus, octonarius, persetosus, spinulosus, zelinkai. All the others are supposed to have simple unbranched bristles.

Having Series of Larger Thicker Bristles.

C. acanthodes, acanthophorus, bogdanovii, brevispinosus, dubius, enormis, heterochaetus, longispinosus, macrochaetus, octonarius, ornatus, ploenensis, persetosus, similis, spinifer, spinulosus, succinctus, tenuis, uncinus, zelinkai.

Posterior Bristles Progressively Longer (exclusive of the larger bristles above noted).

C. arquatus, chuni, entzii, erinaceus, hystrix, larus, macrochaetus, ornatus, pusillus, schultzei, similis, tenuis, zelinkai.

Bristles equal or not Noticeably Longer Posteriorly.

C. brevispinosus, dubius, formosus, gracilis, heterochaetus, jamaicense, linquaeformis, marinus, maximus, serraticaudus, simrothi, slackiae, squammatus, tabulatus.

Notes on Some Species I have Seen.

I have in some of my faunistic lists noted *Chaetonotus larus* and *Ichthydium podura*, but these records have the same value as nearly all such records—*i.e.* none.

At various times I have made studies of species which I could not identify with the assistance of the literature at my disposal. After reviewing nearly all the literature, and taking all the

diagnoses at their face value, it appears that several of these species differ from any of those described in the works known to me.

I would have dealt with these in the usual way and described them as new species, but just as I was finishing this paper Mr. Harring of Washington was good enough to call my attention to a paper by Marcolongo which I had overlooked (**40**). In that paper there are described a number of new species of *Chaetonotus*, as well as a new family and genus.

Mr. Harring has kindly transcribed the descriptions, which appear to be better than such things usually are, but as they are unaccompanied by figures no certain identification is possible. I consider all descriptions of animals in this group unaccompanied by figures as insufficient, but we are promised figures in a forthcoming work by the same author.

In the circumstances I have no alternative but to withdraw my new species in the meantime, but there can be no harm in figuring and describing them as animals I have actually seen.

Several of these are figured on the plate, in company with others which I do not suppose to be new species.

The species of *Chaetura* I can describe with an easy mind, as no one since Metchnikoff has ever described a species of this genus.

Ichthydium sp. (Pl. 19, fig. 23).

A graceful little animal, with very slender neck, deeply trefoliate head and long furca. The branches of the furca are close together at the base, and diverge, tapering to points. No tactile setae are noted, but the animal probably had them. Length about 130 μ.

Habitat.—Amongst *Sphagnum*, Fort Augustus, Scotland, 1904.

It is a good deal like Joblot's "poisson à la tête faite en trèfle," which some have identified as *I. podura*. But what was *I. podura* like? Various animals have been figured by authors under that name, stout animals and thin animals, with long, slender furca or with little blunt knobs. Usually they do not appear to have gone back to Müller, or even to Ehrenberg, to find what *podura* was like. If they had they would have found it was like various things. Müller's *podura* possessed bristles (in some figures), and

so ought to go into Ehrenberg's genus *Chaetonotus*. Its furca was somewhat like the animal I have figured. Ehrenberg's had a different furca.

Lepidoderma sp. (Pl. 19, fig. 29).

A very small animal, with five-lobed head, apparently rhomboid scales, and a short furca with diverging branches. Long, tactile setae on the head. Length, 50 to 60 μ.

The small size might lead to the supposition that the animal is young. In the only instance in which I have seen a Gastrotrich hatch out of the egg the young was of the full adult length of the species. It had only to eat and fill out. From this I suppose that Gastrotricha, like many Rotifera, do not grow appreciably in length.

I say the scales are "apparently" rhomboid, because the regular double diagonal arrangement in rows might give rise to this appearance although the scales were of some other form.

Chaetonotus sp. (Pl. 19, figs. 31*a*–31*b*).

Of medium size; trunk oval, neck well marked, head slightly elongated, five-lobed, without cephalic shield. Mouth nearly terminal, with tuft of hairs.

The bristles on the head and neck are excessively short and fine. At the front of the trunk they become abruptly longer and thicker (though still short) and progressively longer posteriorly. Near the base of the furca there are some half-dozen bristles longer and thicker than any others. None of the bristles are barbed.

The scales from which the hairs spring are elongate hexagons, with the angles so rounded off that they are almost oval. They are arranged in regular diagonal rows, and are separated at their bases by spaces about equal to the width of the scales.

The furca is short, the branches diverging, then converging (enclosing a rhomboid place), obtuse.

No plates can be seen on the head or neck. It is the only species I have seen in which the scales are visible and conspicuous in a specimen in good condition.

Habitat.—Scotland.

Chaetonotus entzii (Dad.) ? (**11**) (Pl. 19, fig. 26).

A large animal, 250 to 300 μ and upwards in length. Head obscurely 3-lobed, with two anterior processes, and two others at posterior angles. Body long, nearly parallel-sided, covered with apparently rhomboid scales, in diagonal rows, and fine short hairs, gradually becoming longer posteriorly. Furca very long, nodose (about twenty nodes in the length), widely divergent at base where separated by small sulcus, less widely divergent above base.

Habitat.—Pond in the Praça Republica, Rio de Janeiro, Brazil; several specimens.

About eight species of long-furcate nodose Gastrotrichs have been described, which have all a suspiciously strong family likeness. Some of these are certainly synonymous, their authors being unaware of the existence of the other species. Daday, who is responsible for the greater number of them, professes to draw distinctions, but he is not very convincing, and moreover I have found the animal here described to be extremely variable.

Daday first described *entzii* as an *Ichthydium*, although it had the characters of *Chaetonotus*. Later he described similar forms as *Lepidoderma*, although some of them at any rate did not fit his genus. Some he compared with *entzii* and with *rhomboides* Stokes, noting that some had not the spines on the head, some had the furca hairy, others smooth, etc. I cannot pretend to sort out all of these here, but content myself with pointing out the family resemblance.

Those I found in Rio had the hairs extremely variable, in some very short, in others not visible at all. I could not doubt that these were all one species, as I could see no other differences whatever. The various species having long nodose furca will be found noted in the list of all described species.

Chaetonotus sp. (Pl. 19, fig. 30).

Large. Head short, 5-lobed, with cephalic shield, neck slightly marked. Body clothed with simple hairs in about fifteen or sixteen longitudinal rows, progressively longer posteriorly. Scales like spear-heads, very like those of *C. larus* (fig. 9). The outline of the body appears crenulate, with very prominent papillae in the narrow part above the furca. About eight longer setae close

to the furca, springing from the papillae. Furca longish, widely divergent, obtuse pointed.

Habitat.—Praça Republica, Rio de Janeiro. The original *larus* is probably not now recognisable, but modern authors have defined it as an animal with scales as in fig. 9, and about eleven longitudinal rows of them. This has more numerous rows. As far as can be judged from the description without a figure, this species is very like *C. laroides* Marco., but that is said to have the scales truncate posteriorly.

It is to be noticed that these very destinctive scales are quite invisible in living or well-preserved specimens. I have only managed to see them in empty, partly shrivelled skins.

Chaetonotus sp. (Pl. 19, fig. 34).

Of moderate size. Head obscurely 3-lobed, with large cephalic shield. Body covered with long, widely out-curved bristles, all barbed, in few rows (six seen in dorsal view) springing from obscure but large hemispherical scales. Close to the furca nine very long, recurved, barbed bristles, three dorsal, six lateral. Branches of furca long, separated by sulcus at base, outcurved, knobbed.

Habitat.—Sydney and New Zealand; a very similar form in Rio, Brazil.

The most obvious character is the widely spreading bristles. Even those nearest the cephalic shield are long, but they are progressively longer posteriorly till near the furca, when a few quite short bristles intervene between the longest dorsal bristles and the special large ones at the furca.

Chaetonotus sp. (Pl. 19, fig. 35).

Of moderate size, relatively broad and squat. Head rounded, 5-lobed. Neck well-marked, short. Trunk parallel-sided. Body covered with apparently rhomboid scales, each bearing a short spine or scale. Furca short, diverging, then converging (enclosing a rhomboid space), the basal portion scaly, the apical portion smooth. There are long tactile setae on the head.

The general form is like that of *Ichthydium ocellatum* Met. (*Lepidoderma ocellatum* Zel.). I saw nothing like the eye-spots ascribed to both those animals.

As there are no type specimens, and only Metchnikoff's description to go by, there is no justification for transferring his species to the genus *Lepidoderma*, as Zelinka does. It is either an *Ichthydium* Ehr. or insufficiently described and unrecognisable.

Zelinka's animal may be the one which I here figure. If so it seems to me that the little triangular scales or spines are homologous with the bristles of *Chaetonotus*, and not with the scales of *Lepidoderma*, and so it should be placed in the former genus.

Habitat.—Summit of Ben Lawers, Scotland, among moss, 1905.

Chaetura piscator sp. nov. (Pl. 19, fig. 33).

Specific characters.—Small; head elongate, egg-shaped, fringed with long setae; neck moderately constricted; body spindle-shaped; each branch of furca forked, branches equal; trunk bearing at least four longitudinal series of fine bristles shaped like fish-hooks, and some straight setae near the furca.

General description.—Length 150 μ, head 50 μ long by 36 μ wide, trunk 30 μ wide, branches of furca about 12 μ; hooks project about 15 μ above the surface.

The head is the widest part of the body. It is fringed by long straight hairs or setae, and bears some larger movable setae which appear to have a tactile function. The neck is slightly constricted, but has a swelling. The dorsal hairs are shaped exactly like fish-hooks, without their barbs. They spring out at nearly right angles to the skin, curve round in the posterior direction, and nearly touch the skin at their tips. I distinguished four rows of them, but in dealing with such excessively fine structures it is not well to state hard-and-fast numbers. Four of the straight setae could be seen dorsally, close by the tail; the four branches of the furca are nearly equal, slightly curved, and have blunt tips.

Technically this is a *Chaetura*, having the branches of the furca furcate, although in Metchnikoff's type species, *C. capricornia*, they are not properly furcate, but bear little branches on the inner side. As in the type, the head is broader than the trunk and there are stiff bristles over the tail. The fishhook-like setae distinguish it from all other known Gastrotrichs.

Habitat.—Amongst moss, Shetland Islands, 1906.

Bibliography.

An asterisk * indicates works in which new species are described.

The works of any importance number scarcely more than a dozen. They are Ehrenberg, 1838 (**19**); Gosse 1851 (**23**), and 1864 (**24**); Metchnikoff 1865 (**41**); Stokes 1887 (**57**); Daday 1882 (**11**), 1901 (**13**), 1905 (**14**), 1910 (**15**); Zelinka 1889 (**71**); Giard 1904 (**22**); Voigt 1904 (**68**); Grünspan 1909 (**26**); Collin 1912 (**9**).

With these works the student will have everything he requires, except a few descriptions of doubtful new species.

Ehrenberg, 1838, summarises the work of the pioneers, and originates a classification. Fräulein Grünspan, 1909, gives the fullest systematic account of the group. Zelinka, 1889, is far and away the best work on the subject, being a painstaking and minute study; but much has been added to our knowledge since his memoir appeared. Collin, 1912, is simply a compilation, but a useful one. The others noted above are the principal systematic works, containing descriptions of many species.

1. Archer, W. In *Quart. Journ. Micr. Sci.*, 14, p. 106, 1874.
   Exhibited at Dubl. Micr. Club, *C. maximus*, *C. gracilis*, and *D. antenniger*; all found in Ireland. Note that the last species can elevate and depress its antennae.
2. Barrois, T. Comptes rendus, July 1887. Trans. in *Ann. Mag. Nat. Hist.*, xx., p. 365, 1877.
   A segmental worm, having the appearance of *Ichthydium*, but differing much in structure. Probably related to *Hemidasys*, *Turbanella*, *Zelinkia*, *Philocyrtis*, which are not Gastrotricha.
3. Bory de St. Vincent. *Encycl. méthod.*, Paris, 1824.
   Furcocerca podura (= *Ichthydium*); *Leucophrya larus* (= *Chaetonotus*).
4. Ibid. Essai des micr., 1826.
   Diceratella larus (= *Chaetonotus*).
5. Bryce, D. In letter to Fräulein Grünspan (*vide* **26**, p. 228). Records *C. zelinkai* for England and Scotland.
6. Bütschli, O. Freilebende Nematoden u. d. Gattung Chaetonotus. *Zeit. für wiss. Zool.*, 26, pp. 385, 390, etc., 1876.
   Classification and Anatomy. Good structural figures of *C. maximus* and *C. larus*.

7. Claparède, E. Misc. zool. III. nouveau genre de Gastérotriches. *Ann. Sci. Nat.*, Ser. 5, vol. 8, p. 18, 1867.

Hemidasys agaso gen. et sp. nov. Not a Gastrotrich, I think.

*8. Collin, A. *Rot. Gastro u. Entoz. Deutsch Ost-Afrika*, 4, p. 9, 1897.

I. macrurum sp. n. A somewhat meagre description, from figure drawn by Stuhlman.

9. Ibid. Gastrotricha. In *Süsswasserfauna Deutschlands*, pp. 240–65, figs. 475–507.

A good account of thirty-two German species, with many useful figures. No new species.

10. Corti. *Osser. micr. sulla Tremella*, p. 89, Pl. 2, 1774.

Ehrenberg thinks the "animaluzzo molle" may have been *C. maximus*. I have not seen the work.

*11. Daday, E. *Ichthydium entzii.*

Termés. Füz., pp. 231–52, Pl. 3, 1882.

New species; full description and good figures. Seems to be the first appearance of a much-described animal which is almost certainly the same as Stokes' *C. rhomboides*, and is probably also Voigt's *C. nodicaudus* and Daday's own *L. hystrix*, *L. elongatum* and *L. birói*, as well as *C. macracanthus* Laut. I found the animal in Rio de Janeiro, and noted that the dorsal hairs vary greatly in length and may be absent, so that the species is both *Chaetonotus* and *Lepidoderma* on occasion!

*12. Ibid. Uj-Guineai Rotatoriak. *Math. es. Termés. Ertes.*, vol. 15, pp. 145–48. (In Hungarian.) 1897.

New species—*C. ornatus* and *L. birói.*

13. Ibid. Mikr. Süsswasserthiere aus Deutsch Neu-Guinea. *Termés. Füz.*, 24, 56 pp., 3 plates, 1901.

Description and figures of the two new species of his previous paper (1897).

*14. Ibid. Süsswasser-mikrofauna Paraguays. *Zoologica*, 18, pp. 72–86, Pls. 5–6, 1905.

Eight new species—*I. crassum*, *L. elongatum*, *C. pusillus*, *C. dubius*, *C. erinaceus*, *C. heterochaetus*, *G. fasciculata*, *G. pauciseta.*

*15. Ibid. Süsswasser-mikrofauna Deutsch Ost-Afrikas. *Zoologica*, 23, pp. 56–9, Pl. 3, 1910.
New species—*L. hystrix*.

*16. Dujardin, F. *Hist. nat. des Zoophytes Infusoires*, pp. 515–69, Pl. 18, figs. 7–8, 1841.
New species—*C. squammatus*.

17. Ibid. Sur un petit animal marin (l'Echinodère). *Ann. Sci. Nat.*, Ser. 3, vol. 15, p. 158, Pl. 3, 1851.
Once classed with the Gastrotricha.

*18. Ehrenberg, C. J. *Organ. in d. Richtung d. kleinsten Raumes*, 2nd Part, Berlin, 1832.
Descriptions (perhaps not his earliest) of *I. podura*, *C. maximus*, *C. larus*, *C. breve*.

19. Ibid. *Die Infusionsthierchen*, pp. 386–90, 1838.
Redescribes the same four species as in 1832.

20. Eichhorn, I. C. *Naturgeschichte der kleinsten Wasserthiere*, p. 35, Pl. 2, fig. R, 1781.
Probably a *Chaetonotus*.

21. Florentin, R. Faune des mers salées. *Ann. Sci. Nat.* (Ser. 8), 10, p. 272, 1899.
Records *Lepidoderma ocellatum* from salt water.

*22. Giard, A. Faunule caractéristique des sables à Diatomées. *C. R. Soc. Biol.*, pp. 1061–5, 1904.
New species—*C. marinus*. Also new genera *Zelinkia* (sp. *Z. plana*) and *Philocyrtis* (sp. *P. monotoides*), which are very doubtful Gastrotricha.

*23. Gosse, P. H. A Catalogue of Rotifera found in Britain. *Ann. Mag. Nat. Hist.*, Ser. 2, vol. 8, p. 198, 1851.
New genus *Dasydytes*, and new species *D. goniathrix* and *D. antenniger*; no figures. *Sacculus viridis* described as a Gastrotrich.

*24. Ibid. The hairy-backed Animalculi. *Intell. Obs.*, V., pp. 387–406, 2 plates, 1864.
New species—*C. slackiae*, *C. gracilis*.
Taphrocampa new genus, described as a Gastrotrich.

25. Grimm, O. A. Fauna im baltischen Meere (is a German rendering of the Russian title). *Arb. d. St. Peter. Natf Ges.*, 8, p. 107, 1877.
Gastrochaeta ciliata new genus and species. No figure given. In a footnote he compares the animal with various

species of *Desmoscolex*, so it is probably not a true Gastrotrich.

*26. Grünspan, Therese. Systematik der Gastrotrichen. *Zool. Jahrb.*, pp. 214–56, 1908.

A comprehensive synopsis of all known species. Seventy admitted species ; six new species and a new genus—*I. tergestinum*, *I. cyclocephalum*, *C. zelinkai* (and var. *gracensis*), *C. tenuis*, *C. multispinosus*, *Setopus primus*(gen. et sp. nov.).

27. Ibid. Die Süsswasser-Gastro-trichen Europas. Eine zusammenfassende Darstellung ihrer Anatomie, Biologie und Systematik. *Ann. Biol. Lacustre*, Bruxelles, vol. 4, pp. 211–365, 61 figs.

28. Hartog, M. Rotifera Gastrotricha and Kinorhynchia. *Cambridge Nat. Hist.*, vol. 2, p. 232, etc., 1896.

A good account and figures of seven known species.

29. Heinrich u. Ehrenberg. Symbolae physicae. Evertebrata. I. Phytozoa, Plates. Berlin, 1828 ; text, 1831.

Pl. I., fig. 11, *Diurella podura* (= *Ichthydium*).

*30. Hlava, S. Syst. Stell. v. *Polyarthra fusiformis* Spencer. *Zoo. Anz.*, 28, pp. 8–9, December 1904.

New genus *Stylochaeta* (sp. *S. fusiformis* Spencer).

31. Imhof, O. Tiefseefauna—Süsswasserbecken. *Zoo. Anz.*, 8, p. 325, 1885.

Found *C. maximus* as an abyssal species in lakes.

32. Joblot. *Nouvelles Observations*, p. 79, Pl. 10, fig. 22, 1718.

" Poisson à la tête faite en trèfle " (= *I. podura*).

33. Kojevnikof, G. Faune de la mer Baltique orientale. *Congrès intern. Zool. II.*, Moscow, pp. 132–57, 1892.

I have been unable to find this work.

34. Lamarck. *Hist. nat. des Animaux sans vertèbre*, p. 447, 1850.

Furcocerca podura (= *Ichthydium*).

*35. Lauterborn, R. Rot.-Fauna d. Rheins u. s. Altwasser. *Zool. Jahrb.*, 7, Syst., pp. 254–73, Pl. 11, 1893.

New species—*Dasydytes zelinkai*, *C. macracanthus*. The description shows *D. zelinkai* as a not very distinct variety of *D. goniathrix* Gosse. No figure is given. *C. macracanthus* appears to be *C. entzii* Dad.

36. Ibid. Die sapropelische Lebewelt. *Zoo. Anz.*, 24, pp. 50–55, 1901.

Dasydytes zelinkai (see previous paper).

37. Lucks, R. Linaugebiet micr.-Wasserbewohner. *Jahrb. Westpreuss. Lehrver. f. Naturk.*, pp. 20–23 (1905), 1906.
List of eight known species in West Prussia.

38. Ibid. Neues aus d. Mikrofauna Westpreussens. *Ber. Westpreuss. Bot.-Zool. Ver.*, 31, pp. 141–2, 1909.
Three additional known species in West Prussia.

39. Ludwig, K. Ü. d. Ordnung Gastrotrichs. *Zeit. für wiss. Zool.*, 26, pp. 219–25, 1875.
A general work, dealing with systematic position, etc. List of thirteen known species.

***40.** Marcolongo, I. Primo contributo allo studio dei Gastrotrichi del lago-stagno craterico di Astroni. *Monitore Zool. Ital. Firenze*, 21, pp. 315–18, 1910.
He gives no figures, but describes a new family Anacanthodermidae, a new genus *Anacanthoderma*, and eight new species—*Chaetonotus laroides*, *C. hirsutus*, *C. minimus*, *C. nodifurca*, *C. decemsetosus*, *C. paucisetosus*, *Dasydytes paucisetosus*, *Anacanthoderma punctatum*.
I have not seen this paper, but received these particulars by favour of Mr. Harring, of Washington. (*Vide* No. **72**.)

***41.** Metchnikoff, E. Wenig-bekannte niedere Thierformen. *Zeit. für wiss. Zool.*, 4, pp. 450–8, Pl. 15, 1865. English trans. in *Journ. Micr. Sci.* (N.S. 6), pp. 241–52, 1865.
New genera—*Chaetura* (sp. *capricornis*), *Cephalidium* (= *Dasydytes*) (sp. *longisetosum*). New species—*Ichthydium ocellatum*, *C. hystrix*, *C. schultzei*.

***42.** Müller, O. F. *Verm. terr. et fluv.*, pp. 66 and 79, 1773.
New species—*Cercaria podura* (= *Ichthydium*), *Trichoda acarus* and *T. anas* (both now = *C. larus*).

***43.** Ibid. *Prod. Zool. Dan.*, 1776.
Trichoda larus (= *Chaetonotus*).

44. Ibid. *Anim. infus. fluv. et marina*, 1786.
Trichoda larus (= *Chaetonotus*).

45. Nitzsch. Infusorienkunde, 1817.
Enchelys podura (= *Ichthydium*).

46. Norrikov, A. V. K. sistematikie Gastrotricha (Russian). *Trud. Obs. Akklim. Moskau*, 6, 1907, pp. 309–47, Pl. 10.
I have not seen this paper, but Mr. Harring, who kindly furnished the reference, says it is largely a translation of Zelinka's paper (**71**) and contains little that is new.

47. Parsons, F. A. In the *Quekett Journal* for 1896–7 there occur some records of Gastrotricha found at the excursions of the Club. I do not know who made the actual identifications, but the records are referred to in Mr. Parsons's name by various authors.

48. Perrier, E. *Traité de Zoologie*, Fasc. 4, pp. 1534–9, figs. 1103–5, 1897.

A general account of six species, with some figures.

49. Perty, M. *Kleinste Lebensformen der Schweiz*, p. 47, 1852.

A few remarks on the group and several known species.

50. Pritchard, A. *History of Infusoria*, 1861.

The earlier editions of Pritchard contain a few notes after Ehrenberg. In 1861 there is a fair account of the group.

***51.** Schimkewitsch, W. M. Neue Species *Ichthydium*. *Nachr. K. Ges. Freunde d. Natur.*, 50, 1886 (*I. bogdanovii*).

***52.** Schmarda, L. K. *Neue wirbellose Thiere*, i. 2, 1861.

Describes two new species as *Ichthydium*—*I. jamaicense* and *I. tabulatum*—which are technically *Chaetonotus*, according to his own generic definition of *Ichthydium*.

53. Schrank, F. v. P. *Beiträge für Naturgeschichte*, 1776.

His *Brachionus pilosus* (Part III., Pl. 4, fig. 32) is, according to Dujardin (**16**, p. 570, footnote), *Chaetonotus larus*.

54. Ibid. *Fauna Boica*, iii., pp. 90–91, 1803.

Trichoda larus (= *Brachionus pilosus*), *T. anas*.

55. Schultze, M. Ueber Chaetonotus und Ichthydium Ehr. *Arch. f. Anat. u. Phys.*, vi., pp. 241–54.

New genus *Turbanella*, which I believe is not a Gastrotrich.

***56.** Spencer. On a new Rotifer, *Polyarthra fusiformis*.

This is a Gastrotrich, since made the type of a new genus, *Stylochaeta*, by Hlava (**30**). *J. Q. M. C.*, 1890, p. 59.

***57.** Stokes, A. C. Observations on Chaetonotus. *The Microscope* (*American*), vol. 7, two parts, January and February, 1887, pp. 1–9, Pl. 1; pp. 33–43, Pl. 2.

One of the most considerable works on the group, in which a great many new species are described. They are all regarded as *Chaetonotus*, the earlier generic distinctions not being admitted.

New species—*C. sulcatus*, *C. concinnus*, *C. loricatus*, *C. rhomboides*, *C. spinifer*, *C. acanthodes*, *C. octonarius*, *C. spinulosus*, *C. longispinosus*, *C. enormis*, *C. acanthophorus*.

Apparently good figures are given of all of these species, and of species of other authors, but Stokes claims indulgence for inaccuracies in all his figures.

58. Ibid. Observations sur les Chaetonotus. *Journ. de Microg.*, 11, 3 parts, February, April, December, 1887, pp. 77–84, 150–3, 560–6, Pl. 1 and 2.

Simply a translation of the American paper, with the same plates.

***59.** Ibid. Observation on a new Dasydytes and a new Chaetonotus. *The Microscope*, vol. 7, pp. 261–5, 1 Pl., 1887.

New species—*D. saltitans*, *C. formosus*.

60. Ibid. Observations sur les Chaetonotus et les Dasydytes. *Journ. de Microg.*, 12, 2 parts, January, 1888.

A translation of the preceding paper.

***61.** Tatem, T. G. New Species of Microscopic Animals. *Quart. Journ. of Micr. Sci.*, N.S. 7, pp. 251–2, 1867.

New species—*Chaetonotus longicaudatus*.

***62.** Thompson, P. G. A new species of Dasydytes. *Science Gossip*, No. 319, 1891.

New species—*D. bisetosus*.

***63.** Voigt, M. Bisher unbekannte Süsswasserorganismen. *Zool. Anz.*, xxiv., No. 640, pp. 191–4, 1901.

New species—*Chaetonotus serraticaudus*, *C. nodicaudus*.

***64.** Ibid. Unbeschriebene Organ. Plön. Gewässern. *Zool. Anz.*, xxv., No. 660, pp. 35–9, 1901.

New species—*Ichthydium forcipatum*, *Chaetonotus chuni*, *Dasydytes stylifer*.

***65.** Ibid. Rot. u. Gast. d. Umgebung v. Plön. *Zool. Anz.*, xxv., No. 692, pp. 673–81, 1902.

He names nine species as new, but gives no descriptions or figures except of one. Eight of them had been described in earlier papers. The nine names are *Ichthydium forcipatum*, *Aspidonotus paradoxus* (n. gen., n. sp.), *Chaetonotus linguaeformis*, *C. nodicaudus*, *C. serraticaudus*, *C. uncinus*, *C. succinctus*, *C. chuni*, *Dasydytes stylifer*. He describes *Aspidonotus* and (p. 681) figures one scale.

*66. Ibid. Drei neue Chaetonotus-Arten a. Plön. Gewässern. *Zool. Anz.*, xxv., No. 662, pp. 116–18, January, 1902.

New species—*C. linguaeformis, C. succinctus, C. uncinus.*

*67. Ibid. Eine neue Gastrotrichenspecies (*Chaetonotus arquatus*) aus dem Schlossparkteiche zu Plön. *Forschber. Biol. Stat. Plön.*, x., pp. 1–4, 1903.

68. Ibid. Rotatorien u. Gastrotrichen d. Umgebung von Plön. *Plöner Forsch.-ber.*, xi., 180 pp., 1904.

He records twenty-three species and describes nine as new, but these have been described in earlier papers. He renames the genus he had called *Aspidonotus*, making it *Aspidiophorus*, as he found that the former name was preoccupied.

*69. Ibid. Nachtrag zur Gastrotrichen-Fauna Plöns. *Zool. Anz.*, xxxiv., No. 24/25, pp. 717–22, 1909.

New species—*Chaetonotus ploenensis, C. simrothi, Dasydytes dubius, D. festinans, D. ornatus.*

70. Wagner, F. Der Organismus der Gastrotrichen. *Biol. Centralb.*, 3, No. 7/8, 1893.

*71. Zelinka, C. Die Gastrotrichen. *Zeit. f. wiss. Zool.*, 49, pp. 299–476, Pl. 11–15, 1889.

An important paper, the most careful and scientific that has appeared on the subject. He gives a good and full account of the anatomy, a good bibliography, and a good *résumé* of all the systematic work on the group, quoting most of the authors' original descriptions. Some previously described species escaped his notice, as *Ichthydium entzii* Dad. Two new genera and four new species are described. The genus *Gossea* is framed to contain Gosse's *Dasydytes antenniger*, *Lepidoderma* for Dujardin's *Chaetonotus squammatus*, with *C. rhomboides* Stokes, *Ichthydium ocellatum* Metch., and *C. concinnum* Stokes. *Lepidoderma* is an unfortunate genus, as the type species (*C. squammatus* Duj.) is spiny and a true *Chaetonotus*. *C. rhomboides* Stokes is usually spiny, and *I. ocellatum* Metch. is not stated or figured by its discoverer to have scales.

The new species are—*Chaetonotus similis, C. brevispinosus, C. macrochaetus, C. persetosus.*

72. Marcolongo, Ines. I Gastrotrichi del lago-stagno craterico di Astroni. *Atti Acc. Sci. Fio. e Nat. Napoli*, vol. 14.

Explanation of Plate 19.

Scale and hair of:

Fig. 1. *C. macrochaetus* Zel. (After Zelinka.)
„ 2. *C. hystrix* Metsch.
„ 3. *C. similis* Zel. (After Zelinka.)
„ 4. *C. maximus* Ehr. (After Zelinka.)
„ 5. *C. persetosus* Zel. (After Zelinka.)
„ 6. *C. pusillus* Dad. (After Daday.)
„ 7. *C. heterochaetus* Dad. (After Daday.)
„ 8. *C. schultzei* Metch. (After Zelinka.)
„ 9. *C. larus* Müll. (After Ludwig.)
„ 10. *C. erinaceus* Dad. (After Daday.)
„ 11*a*. *C. succinctus* Voigt, one of the long bristles. (After Voigt.)
„ 11*b*. *C. succinctus* Voigt, scale from posterior part. (After Voigt.)
„ 12. *C. hystrix* Metsch. (After Zelinka.)
„ 13. *C. nodicaudus* Voigt. (After Voigt.)
„ 14. *Aspidiophorus paradoxus* Voigt. (After Voigt.)
„ 15. *Lepidoderma elongata* Dad. (After Daday.)
„ 16. *C. brevispinosus* Zel. (After Zelinka.)
„ 17. *C. arquatus* Voigt. (After Voigt.)
„ 18. *C. simrothi* Voigt. (After Voigt.)
„ 19. *C. zelinkai* Grün. (After Grünspan.)
„ 20. *C. uncinus* Voigt. (After Voigt.)
„ 21. *C. chuni* Voigt. (After Voigt.)
„ 22. *C. linguaeformis* Voigt. (After Voigt.)

„ 23. *Ichthydium* sp. (?).
„ 24. *Lepidoderma loricata* Stokes. (After Stokes.)
„ 25*a*. *Dasydytes goniathrix* Gosse. Drawn from nature.
„ 25*b*. *D. goniathrix* Gosse. A single seta.
„ 26. *C. entzii* Dad. (?). Differs from Daday's in having the furca without hairs.
„ 27. *Dasydytes bisetosus* Thomp. Drawn from nature.
„ 28*a*. *Gossea antennigera* Gosse. Drawn from nature.
„ 28*b*. *G. antennigera* Gosse. Scale and hair.
„ 29. *Lepidoderma*, very small species. Drawn from life.

Fig. 30. *Chaetonotus* sp. (?). Scales as in *C. larus* (fig. 9), but rows more numerous.

„ 31*a*. *Chaetonotus* sp. (?). With very distinct rhomboid scales.

„ 31*b*. *Chaetonotus* sp. (?). Three of the scales.

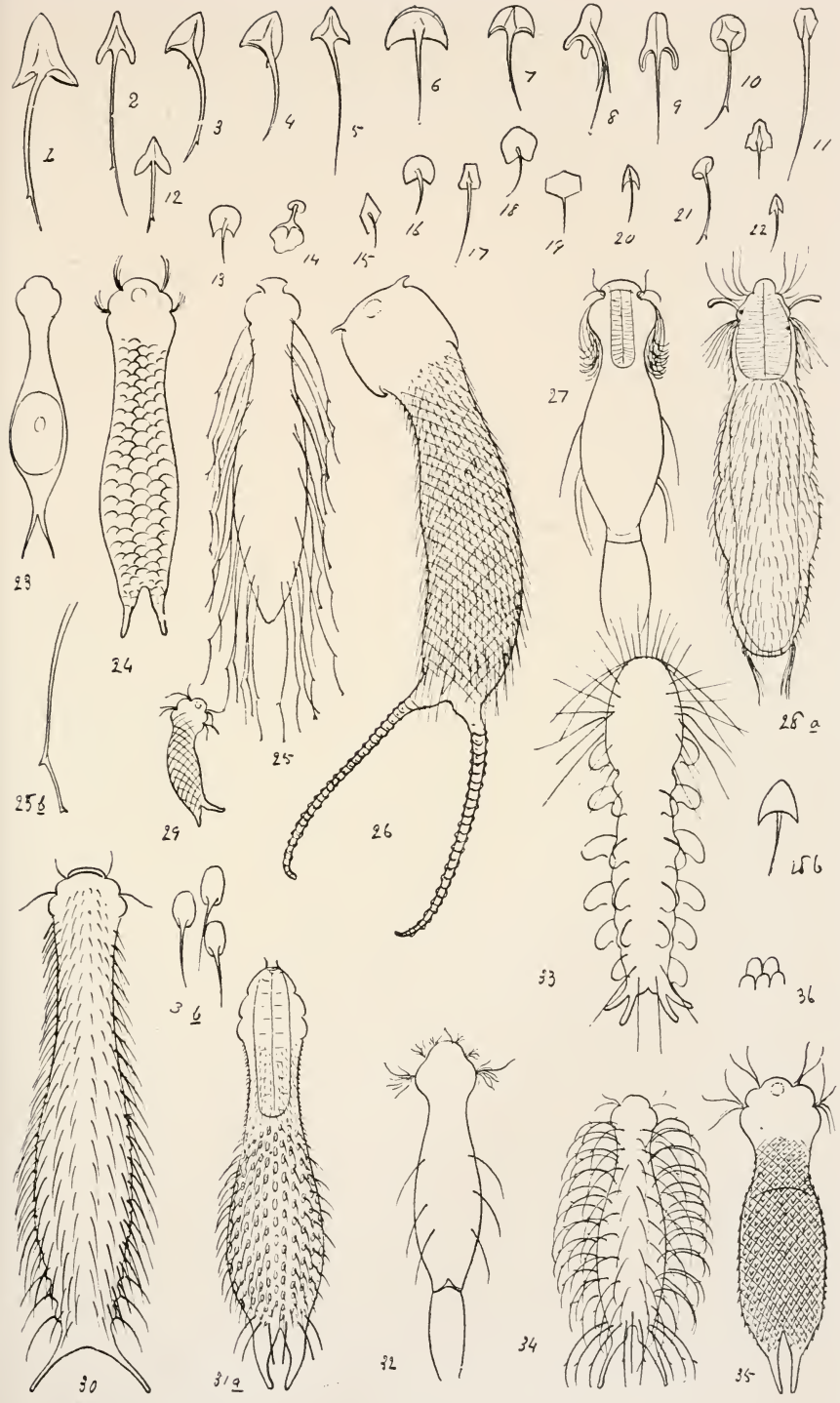
„ 32. *Setopus primus* Grün. (After Grünspan.)

„ 33. *Chaetura piscator* sp. n.

„ 34. *Chaetonotus* sp. (?). All hairs long, widely spreading.

„ 35. *Chaetonotus* or *Lepidoderma*. Like the animal figured by Zelinka as *L. ocellatam* Met., but I saw no eyelike bodies. Metchnikoff did not describe his animal as scaly.

„ 36. Scales of *C. tenuis* Grün. (After Grünspan.)



J. MURRAY, *del. ad nat.*

GASTROTRICHA.

NOTES

ON A NEW METHOD OF MEASURING THE MAGNIFYING POWER OF A MICROSCOPE.

By Edward M. Nelson, F.R.M.S.

(*Read June 24th*, 1913.)

Many microscopists, at one time or another, will have experienced some trouble about the determination of the *combined* magnifying powers of their objectives and eyepieces. Some never measure them at all, and rely upon the manufacturer's catalogues for the results. This is not very satisfactory, for neither objectives nor eyepieces turn out to be at precisely their nominal foci ; and if both these should happen to be either in excess or deficit the actual magnifying power will differ considerably from that given in the catalogue. Therefore it will be better for every one to measure the magnifying powers of the lenses of their microscope.

There are two well-known methods of doing this. The first, and perhaps the simplest, is to employ a photomicrographic camera to measure the magnified image of the stage micrometer when projected on to the ground glass at a distance of ten inches. The second is to project the magnified image of the stage micrometer, by means of some sort of a camera lucida, on to a scale, distant ten inches as before.

All this appears delightfully simple, but when examined more carefully it is not really so. First, the photomicrographic-camera method requires a dark room, or the measurement must be made at night, and of course it is sure to happen that when the camera is most wanted it is not available. This is just what has occurred to me. My photomicrographic camera and stand, which

are large and heavy, are packed away; it would take some hours to unpack them, clear out a room for their reception, bring them in and set them up, so I have to be content with some other means of measuring magnifying powers.

The second method, viz. that of employing a camera lucida, also appears to be very simple, and so it is when a Powell No. 1 stand is used, which has its optic axis ten inches from the table, when inclined horizontally; a Beale's neutral tint fitting on the "capped" eyepieces answers perfectly—some attention, however, is necessary to regulate the illumination, both in the tube and on the rule, otherwise the coincidences of the lines cannot be observed. But suppose a continental eyepiece is used, what then? The Beale camera will not fit, and all the simplicity of one's arrangements and apparatus fails. If the microscope is not a Powell's No. 1, then it must be placed upon a box, and the distance of the rule adjusted by means of other boxes, books, etc. With a Continental microscope matters are no better. One has the simplicity of the Abbe camera, with its cleverly planned device for regulating the illumination of the stage micrometer and of the rule, but suppose the eyepiece is of the positive compensating type, what is to be done? The camera will not fit and cannot be used. There are other cameras, both of the right-angled and of the oblique type; some eyepieces they fit and others they do not. These difficulties are not imaginary, for I have experienced all of them at one time or another. The apparatus I now use is the old-fashioned Wollaston's camera, mounted on a table screw clamp. This can be used with every kind of eyepiece; it is, however, troublesome to work with, and it requires some practice to obtain a coincidence of the scales—how anybody can execute a drawing with such an apparatus is, to me, quite incomprehensible!

I have devised an entirely new method by which all these worrying little troubles may be avoided. First, it is necessary to determine the "constant" of the eyepiece with a given tube length. This is easily done, and when done it should be recorded, or better still engraved on the eyepiece tube. To find the "constant" of an eyepiece with a given tube length, first determine the combined magnifying power of that eyepiece on the given tube length with any objective, say one of medium power, such as a $\frac{2}{3}$-in. or $\frac{1}{2}$-in. or $\frac{4}{10}$-in. focus. Secondly, measure

the exact diameter of the field by means of the stage micrometer. The product of these two quantities is the constant of that eyepiece with the given tube length.

Example: objective $\frac{1}{5}$-in., eyepiece compensating × 8, tube length 170 mm., measured magnifying power 280 diams.: measured field 0·023 in. Product is 6·44, which is the constant of that eyepiece for 170-mm. tube.

The power of any other objective with this eyepiece and tube length can be determined by merely measuring the diameter of its field by the stage micrometer; for the magnifying power will obviously be the eyepiece constant divided by the diameter of the field.

Thus, the problem of measuring the combined magnifying power is brought down to the bed-rock of simplicity. No camera, no regulation of illumination, no ten inches to measure; in brief, nothing to do but to count the number of divisions of the stage micrometer in a diameter of the field and then divide this into the eyepiece constant.

Example 1. With the same ×8 compensating eyepiece and 170-mm. tube a $\frac{1}{4}$-in. objective gave a diameter of field of 0·0165 in. The magnifying power therefore is $\frac{6{\cdot}44}{0{\cdot}0165} = 390$.

Example 2. With the same × 8 compensating eyepiece and 170-mm. tube a $1\frac{1}{2}$-in. objective gave a diameter of field of 0·185 in. The magnifying power therefore is $\frac{6{\cdot}44}{0{\cdot}185} = 35$.

The determination of the constant is scarcely any more trouble than the measurement of the magnifying power of one objective, and when once found need not be determined again; it would ndeed be most helpful if manufacturers would measure these constants and engrave them upon the tubes of their eyepieces.

Obviously the diameter of the field can be measured while the microscope work in hand is being carried on, for it disturbs neither the microscope nor its adjustments.

This method has been tested with thirty-three object glasses, ranging from a 3-in. to a $\frac{1}{12}$th of 1·4 N.A., by fourteen different makers, and with various eyepieces, on three different microscopes with different tube lengths, and it has been found correct.

My best thanks are due to Mr. Grundy for his kind assistance and notes. Further experience has shown that in determining the "constant" it is better to measure the magnifying power by

direct projection on to a scale, without the intervention of any camera lucida or drawing instrument; the position of the Ramsden's disc, from which the 10-in. projection distance is measured, is easily found by means of a piece of ground glass. An excellent scale for the measurement of low powers is a Lufkin 3-in., No. 2111, price 1*s*.

[Practical members may, by this time, be ready to ask, "What is the practical use of this system?" As a general answer it might be said that it shows how the materials for an important microscopical measuring tool can be easily determined.

But another practical reason for my taking interest in our veteran member's paper is the hope that it will stimulate some of us to take an increased interest in microscopical measurements.

I hardly need to impress on members the value of actually measuring objects, beyond offering a reminder, that measurements are the fundamental basis of microscopical science, and of every branch of science. Some would, perhaps, claim to put mathematics in this honourable position, but mathematics would be in a most sorry plight without measurements in various forms.

Mr. Nelson, in a letter, says: "The combined magnifying power is wanted for drawings. Beale's method of exhibiting a drawing of the stage micrometer with the picture is quite the best, but it is adopted by only a few authors." And he mentions an instance of great trouble being caused by some drawings in books on microscopical subjects having the magnifications wrongly stated in the legend.

It will have been noticed that Mr. Nelson has, hitherto, confined the use of the "eyepiece constant," *for one eyepiece*, to one definite tube length for one constant; but used it for getting the total magnification with varying powers of objectives.

Tests have, however, shown that the total magnification can be determined, by his method, for different tube lengths just in the same way as for different powers of objectives. Mr. Nelson himself says that "increase of tube length increases the power and, of course, diminishes the field, and is just the same as putting a higher-power objective on the nosepiece; the constant of the eyepiece remains the same." In support of this statement, I give below a few of the results of experiments made by Mr. Nelson not many days ago.

TESTS WITH POWELL & LEALAND'S LOW-ANGLED $\frac{1}{2}$-IN. OBJECTIVE.

Eyepiece.	Tube length.	Diameter of field.	Magnifying power.	Eyepiece constant.
No. 1	12 in.	0·036	103	3·708
„	6 „	0·0675	56	3·78
No. 2	12 in.	0·031	135	4·185
„	6 „	0·0615	70	4·305
No. 4	12 in.	0·0267	267	7·129
„	6 „	0·052	135	7·02

OTHER TESTS WITH $\frac{1}{2}$-IN. OBJECTIVE.

	Eyepiece constants.	
Eyepiece.	Tube length, 8·75 in.	Tube length, 6·7 in.
A (R)	6·13	6·04
Z 12 C	5·2	5·1
W 1	3·69	3·54
2	4·13	4·10
K 3	5·64	5·6
	Tube length, 14·6 in.	Tube length, 5·3 in.
K 3	5·62	5·64
Magnifications . .	250	94

Notice how nearly alike the eyepiece constant is for each pair of tests when different tube lengths are used, but the same eyepiece and objective. The last pair are practically the same, although the tube lengths vary to an extraordinary extent. Mr. Nelson says that "they are all done with extreme accuracy by projection. In every case the Ramsden's disc was found and the screen placed ten inches from it." The magnifications were 250 and 94 diameters.

There is another easy way in which the information given by the "eyepiece constant" may be used for determining the total magnification for any tube length. Suppose, for example, the eyepiece constant has been obtained with a given objective, eyepiece, and tube length, a record being made; then it is only necessary to work a very simple proportion sum to determine—at any time—the total approximate magnification with any tube

length. All other conditions being the same, the total magnification will be proportional to the tube lengths used.

Take the extraordinary difference of tube length shown by the figures given below :

Tube length.	Magnification.
14·6 in.	250
5·3 in.	94

Then

$$\frac{\text{Magnification with long tube} \times \text{short tube length}}{\text{Long tube length}} = \frac{250 \times 5{\cdot}3}{14{\cdot}6} = \text{Magnification for short tube length.}$$

And

$$\frac{\text{Magnification with short tube} \times \text{long tube length}}{\text{Short tube length.}} = \frac{94 \times 14{\cdot}6}{5{\cdot}3} = \text{Magnification for long tube length.}$$

It is also worth mentioning that the diameter of the field may be measured in millimetres, instead of inches, if millimetres are used when determining the value of the eyepiece constant. And members will probably find this a great convenience.

J. Grundy.]

PROCEEDINGS

OF THE

QUEKETT MICROSCOPICAL CLUB.

At the meeting of the Club held on March 25th, 1913, the President, Prof. A. Dendy, D.Sc., F.R.S., in the chair, the minutes of the meeting held on February 25th were read and confirmed.

Messrs. J. T. Cook, David Henry Shuckard and W. E. Ford-Fone were balloted for and duly elected members of the Club.

The Hon. Secretary announced that Mr. G. T. Harris, of Sidmouth, a former member of the Club, had made a very handsome donation in the form of a type collection of Hydrozoa, numbering 72 preparations. These had been collected on the south-west and west coasts of England, and should prove very useful to any member making a systematic study of the group, especially as the slides are accompanied by a résumé as a help in diagnosing the more difficult species. Mr. Harris also sent a paper which will be read at the next meeting, on "The Collection and Preservation of the Hydrozoa."

A vote of thanks to Mr. Harris for his valuable donation was proposed by the President, and carried by acclamation.

Mr. A. A. C. Eliot Merlin, F.R M.S., sent for exhibition five photomicrographs, taken at ×320, of diatoms from a slide prepared by the late C. Haughton Gill (see Journal R.M.S., 1890, p. 435). They were of *Epithemia turgida*, *Stauroneis phoenicenteron*, *Pinnularia major*, under surface showing perforations on ribbing partly filled with the mercurous sulphide, and two others.

A paper by Messrs. Heron-Allen and Earland, "On some Foraminifera from the Southern Area of the North Sea, dredged by the Fisheries cruiser '*Huxley*,'" was read by Mr. Earland. Mr. Earland said that after the reading of the paper by Mr. Heron-Allen and himself, "On the Occurrence of *Saccammina*

sphaerica and *Psammosphaeria fusca*," before the "*Challenger*" society in October of last year, Mr. J. O. Borley, of the Fisheries Department of the Board of Agriculture, suggested that it would be interesting if they continued their investigations in the southern area of the North Sea with a view to determining the distribution of the two species in that area. This, after some hesitation, they agreed to do; but with little expectation that any observations of interest would result, as Mr. Borley had already confirmed, from his personal experience, the generally held opinion that Foraminifera of all kinds were of extremely rare occurrence in these waters. The shallowness of the sea, and consequent disturbance due to wave and tidal action, were considered to be factors limiting the possibilities of Rhizopodal distribution. Material was examined from six stations representing two widely separated areas of the North Sea, three stations being far to the north-east of the Dogger Bank near the Great Fisher Bank, while the other three stations were in the belt of deep water which lies to the west of the Dogger, close in to the Northumberland coast. The depths ranged between 31 and 45 fathoms.

A number of photomicrographs were projected upon the screen, and briefly described by Mr. Earland. *Nubecularia lucifuga* (Defrance), a southern form, has an extended range as far as the English Channel. It is common at Bognor and Selsey, and a few specimens had been found near the Orkneys and in Moray Firth. *Miliolina seminulum* (Linné) occurs at every station in both areas. It is the dominant miliolid of the North Sea, and is of world-wide distribution. Of the two species especially searched for *Psammosphaera fusca* (Schulze) was found to occur at all stations except one in the inshore area. *Saccammina sphaerica* (Sars) does not occur in any of the outer, or Great Fisher Bank, collections, but does occur at two inshore stations. The specimens found were extremely small. The dominant arenaceous form was *Reophax scorpiurus* (Montfort). The dominant Textularian was *Verneuilina polystropha*. It occurred in great numbers and variety at every station. The genus Lagena is abundantly represented in the inshore station dredgings, twenty-eight species being recorded, while at the outer stations only eight species were found. *Truncatulina lobatula* (W. and J.), *Nonionina depressula* (W. and J.), and *Polystomella*

striato-punctata (F. and M.) occur abundantly everywhere, and form the bulk of all the cleaned material.

The President, in proposing a vote of thanks for the paper, said he much admired the photographs shown, which were the best of the kind he had seen. He would like to ask Mr. Earland, with regard to the criteria of specific characters, How could one tell one species from another, seeing that there is so much variation within the same species?

The vote of thanks was carried unanimously.

In replying, Mr. Earland said he had to thank Mr. A. E. Smith for making the negatives, and Mr. Lovegrove for the lantern slides. Regarding specific differences, probably Prof. Dendy would have no difficulty in identifying sponges which he (Mr. Earland) would not be able to tell one from another. There are constant points always present which make it more or less easy to diagnose within certain limits. As regards specific features in Foraminifera, there are none such as we find between, say, a cat and a dog. Probably generic differences in Foraminifera are about equal to specific differences in higher forms.

Mr. D. Bryce gave a résumé of a paper he had contributed on "Five New Species of Bdelloid Rotifers." Four of the new species belong to that important section of the Philodinidae in which the food is formed into pellets after passing through the mastax, and are assigned to the genus Habrotrocha. The new species are *H. munda*, *H. torquata*, *H. spicula*, and *H. ligula*. The fifth species, *Callidina Bilfingeri*, belongs to the more numerous section of the same family in which the food is not at any time agglutinated into pellets, and being oviparous, and possessed of three toes, is a member of the genus Callidina, as now restricted.

The President said they were all much indebted to Mr. Bryce for bringing these interesting details before them.

A vote of thanks to Mr. Bryce for his communication was carried unanimously.

At the meeting of the Club held on April 22nd, 1913, the Vice-President, E. J. Spitta, L.R.C.P., M.R.C.S., in the chair, the minutes of the meeting held on March 25th were read and confirmed.

Messrs. F. J. Cheshire, Henry Edwards, and H. D. Rawson were balloted for and duly elected members of the Club.

The List of Donations to the Club was read and the thanks of the members voted to the donors.

Mr. C. D. Soar, F.R.M.S., read a note describing two new species of water-mites. These were *Arrhenurus Scourfieldi* sp. nov. and *Acercus longitarsus* sp. nov.. The first was taken by Mr. Scourfield in Cornwall, in fresh water, in the autumn of 1912. It belongs to the sub-genus Megalurus, female unknown. The new species of Acercus is named from the unusually long tarsi found in the fourth pair of legs. Locality, South Devonshire, female unknown. Mr. Soar also said that Mr. Williamson, F.R.S.E., in working out the material on the genus Sperchon had found two species new to Britain, and two that have only been recorded for Ireland. These were *Sperchon clupeifer* Pier, sub-genus Hispidosperchon, from Oban and Norfolk Broads. *Sperchon tenuabilis* Koen, sub-genus Hispidosperchon, from Oban. Recorded by Halbertin Clare Island Survey for Ireland. *Sperchon papillosus*, Sig. Thor, sub-genus Squamosus, Oban, recorded by Halbert for Ireland; and *Sperchon Thienemanni*, Koen, sub-genus Rugosa, from Derbyshire. Drawings of the two new species were exhibited.

The Chairman said they were all deeply indebted to Mr. Soar for bringing these new species of Hydrachnidae before them, and they would be able to appreciate the value of the paper more when in print. The drawings in illustration of the species described were very fine indeed.

The thanks of the meeting were unanimously voted to Mr. Soar for his paper.

In the absence of the author, the Hon. Treasurer, Mr. F. J. Perks, read a paper on "The Collection and Preservation of the Hydroida," by Mr. G. T. Harris, of Sidmouth, a former member of the Club. The author said that the Hydroida are too well known as affording both beautiful and interesting objects to need any eulogy at his hands. Bearing in mind that this paper is written more for the help of the novice than as a communication offering original matter, the writer wished to safeguard himself from any charge of carelessness by warning the uninitiated that collecting, say, rotifers and collecting hydroids are two totally and very dissimilar things.

A hearty vote of thanks was given to Mr. Harris for his interesting paper, which was well illustrated by about twenty preparations from those which he had presented to the Club at the March meeting. The preparations were arranged, mostly with dark-ground illumination, under microscopes kindly lent by Messrs. H. F. Angus & Co.

The Chairman, in moving a vote of thanks to Messrs. Angus, which was carried by acclamation, said that in London members took for granted that there was never any difficulty in getting their optician friends to lend the Club any reasonable number of microscopes; but, as he had found by recent experience, outside of London such a thing was practically an impossibility; even in a large town the number of microscopes available was very small. By being reminded of this he hoped they would more fully appreciate their good fortune.

At the meeting of the Club held on May 27th, 1913, the President, Prof. A. Dendy, D.Sc., F.R.S., in the chair, the minutes of the meeting held on May 22nd were read and confirmed.

Messrs. Stanley Hall and Reginald Hook were balloted for and duly elected members of the Club.

The list of donations to the Club was read and the thanks of the members were voted to the donors.

The President said that for many years past a number of pamphlets, etc., had been received by the Club, which, not being considered of sufficient value to bind, had been allowed to accumulate and were stored in a room downstairs. These had long been a kind of white elephant to the Committee, who had at length decided to deal with them, and had appointed a sub-committee for this purpose. These gentlemen had gone through them and had come to the conclusion that a large mass of this material must be disposed of, and the question arose as to how this was to be done, and it had been resolved to offer the bulk to some dealer in second-hand books, but first of all to offer them to the members of the Club. For this purpose, lists would be prepared and laid upon the table at the next Gossip meeting and again at the next Ordinary meeting, for members to inspect and to make offers for any which they might care to possess. The

Librarian was empowered to receive such offers for them and to accept those which he deemed satisfactory. It was not possible to bring them up for inspection, as there was about a ton and a half of them.

A visitor, Mr. J. Watson, exhibited multiple images formed by the cornea of the eye of a hive bee mounted dry.

Mr. J. Watson said the slide was that of the eye of a honey bee prepared so as to show the portrait of the bee-keeper in every facet just as the bee would see it. He had been told it could be done with the eye of a beetle, but that the hairs on the eye of the bee made it a difficult matter to accomplish; but by mounting the object in the way he described, so that the hairs were free from pressure on the under side of the slide, he had succeeded in obtaining the desired result, and he had obtained a good photograph of it with half an hour's exposure.

The President said that at a Society such as theirs it was needless to explain that this was not the view which the bee got, as no doubt in some way it saw a single image, but he just mentioned this to prevent any mistake, as he thought he heard it stated that this was how the bee saw the bee-master. Multiple images such as were shown could be got in a variety of ways, and he remembered that exactly the same thing was done at one of the Royal Society's soirées with the epidermic cells of a plant. They were, however, much obliged to Mr. Watson for bringing and explaining his exhibit.

Mr. R. Inwards had found that a small knob fitted near the hinge-joint of the stop-carrier of substage condensers was more convenient in working than having to feel on the right for the usual long projecting end, which is very often in close proximity to the iris-handle.

Mr. T. A. O'Donohoe read a paper illustrated by a number of lantern photographs, at various degrees of magnification, of the "Minute Structure of *Coscinodiscus asteromphalus* and of the two species of Pleurosigma, *P. angulatum* and *P. balticum*. Mr. O'Donohoe then showed an interesting series of photographs, at various magnifications, of *P. balticum*, some showing fine, hair-like, bent fibrils breaking away from the valve. Others showed the outer membrane breaking up into fibrils, and sometimes isolated dots.

Mr. W. E. Brown said that the fibrils shown by Mr. O'Donohoe

had been known to him for a long time, but he had never regarded them as structure, but rather as salt which had crystallised out after mounting. All these fibrils consisted of rows of dots connected by bars, and there always seemed to him to be some difference between these and the general structure.

Mr. E. Pitt exhibited and described the Cambridge, Minot and Spencer microtomes, and, after the adjournment of the meeting, gave a demonstration of ribbon section-cutting.

A vote of thanks was accorded Mr. Pitt for his exhibition.

At the meeting of the Club held on June 24th, 1913, the President, Prof. A. Dendy, D.Sc., F.R.S., in the chair, the minutes of the meeting held on May 27th were read and confirmed.

Messrs. Frank Deed, C. Tierney, D. L. Newmarch, E. L. Fenwick, and H. H. Dean were balloted for and duly elected members of the Club.

The list of donations to the Club was read, and the thanks of the members voted to the donors.

The Hon. Secretary read a note from Mr. E. M. Nelson describing Koristka's new loup. The writer said that in 1885 he brought to the notice of the Club the then new Zeiss-Steinheil loups, which had just arrived from Jena. These lenses have been very popular, and have since been copied by every maker, both here and on the Continent.

There is now a new form of loup with which the Club should be acquainted; it is the achromatic doublet of Koristka. The following are the measured particulars (not taken from a catalogue):

Doublet,	power 10,	field 1½ cm.,	working distance 2 cm.						
Top lens alone,	,,	5½,	,,	2	,,	,,	,,	4	,,
Bottom lens alone,	,,	3½,	,,	4	,,	,,	,,	5	,,

The defining power of this loup is excellent, and prolonged work with it seems easier than with a Steinheil; somehow or other work with a Steinheil is tiring to the eye. The price of this fine lens, in a wooden box, is only 12*s.*, but although the price is so low, the quality of workmanship is particularly high. Among cheap loups we so often find that the lenses are imperfectly polished, the threads of the screws badly cut, so that they do not engage readily, and the quality of materials used

inferior. But this new loup exhibits none of these defects, and Koristka is to be congratulated on having brought out at a low figure a loup which compares favourably in the quality of its finish with the most expensive grades of work in this line. This high standard of workmanship extends also to Koristka's objectives, eye-pieces and other apparatus.

Mr. A. A. C. Eliot Merlin, F.R.M.S., sent a note on "Secondary Hairs on Foot of a Ceylon Spider." The main hairs on the foot of a very large species of Ceylon spider, the name of which is unknown, have proved to be densely covered with small short spines or hairs so transparent as to be observable with difficulty even by means of an oil-immersion objective. The specimen examined was obtained and mounted in balsam by the late Staniforth Green, who was for many years resident at Colombo. When the main hairs are viewed with a dry lens of moderately large aperture they plainly exhibit a regular clotted structure, this being composed of the ring root sockets of the secondary spines, which are themselves so transparent in the balsam mount as to require great aperture to define properly. It is suggested, however, that hairs from this, or similar, large species of spider might be mounted in glycerine jelly and might then exhibit the spines more easily. The preparation in which the spines have been noted happens to be, like most entomological mounts intended for examination under low or medium powers, provided with a cover-glass of considerable thickness, while the foot itself is large and by no means flat. Under these conditions an ordinary oil-immersion objective could not be employed, but fortunately a Powell one-twelfth achromatic, of measured N.A. 1·27, obtained some fifteen years ago, possesses quite abnormal working distance compared with recent productions of similar, or slightly greater, aperture, and is to oil-immersion lenses what the new one-sixth moderate aperture objectives of great working distance are to dry systems. The lens in question has on several occasions proved invaluable for the examination of minute structure in ordinarily mounted entomological specimens. A photomicrograph at × 60 accompanied the paper for identification purpose, and was exhibited.

Mr. Nelson sent for exhibition a section of Green Trap, basic igneous rock, a crystalline aggregation of serpentine. This, he wrote, might easily be mistaken for a piece of fossil nummulite, or

wood. It is probable that the fossil known as *Eozoon canadense*, from the Laurentian serpentine, is of a similar nature.

Mr. H. Sidebottom contributed a valuable paper on "The Lagenæ of the South-West Pacific." Mr. A. Earland, F.R.M.S., in introducing this paper, said it was a very lengthy and valuable one, and the Club would be proud to include it in the Journal. It is Part 2 of a paper published in the April 1912 issue of the Journal. By the kindness of Mr. H. F. Angus, who arranged an exhibition frame for the drawings, he was able to exhibit some of Mr. Sidebottom's beautiful drawings. The majority of the stations from which the specimens dealt with were derived (if not all) lie within the region of the South Pacific known to oceanographers as the "Aldrich Deep." This area lies to the east of New Zealand, between 15° and 47°, and covers about 613,000 square miles. Three soundings exceeding 5,000 fathoms have been recorded in this area by Commander Balfour in H.M.S. "*Penguin*" in 1895. The deepest sounding yet made, however, is one in the "*Challenger*" Deep, near Guam, in the Ladrone Islands. This is 5,269 fathoms, nearly six miles. The Aldrich Deep has the second deepest record, 5,155 fathoms. None of the material discussed in this paper comes from the deepest parts of the area. The depths given by Mr. Sidebottom range between 328 fathoms and 4,278 fathoms, but the majority are under 2,000 fathoms. No details are given of the nature of the material from which the specimens were derived, and possibly the information was not in the author's possession, as the majority, at any rate, of the specimens had been picked out by Mr. Thornhill prior to his death, when the type slides passed into the hands of Mr. Sidebottom for classification and description. It may, however, be fairly surmised that, owing to the distance of the area from any land, none of the samples would be terrigenous deposits, but would be true oceanic deposits. Globigerina and Pteropod oozes in the lesser depths, passing into pure Globigerina ooze, and, beyond the 2,000-fathom line, into Red Clay. The presence of a varied and rich fauna of Lagenæ in the deep water of the South Pacific has been recorded by the "*Challenger*." Some of the stations of that ship lie within the same area as the "*Penguin*" material worked by Mr. Sidebottom, but the "*Challenger*" material was either very poor in specimens compared with the "*Penguin*," or it was very incompletely

worked out. The genus Lagena, while of world-wide distribution and occurring at all depths, presents some rather curious anomalies as regards its occurrence in any abundance. It would probably be almost impossible to make a dredging or a shore gathering in any part of the world without finding the genus represented in the material. But, Mr. Earland said, from practical experience, both of deep and shallow water dredging and of shore collecting, he knew that in one sample the genus may be extremely rare, while in another of similar material taken a few miles away, under similar conditions of depth, the genus may be abundant and varied. The reason for such a difference is obscure, but is possibly based on the proportion of mud in the deposit. Legena as a genus is a lover of still and muddy bottoms. Globigerina oozes are, as a general rule, singularly poor in Lagenæ: hence the greater wonder at the richness of the fauna in these "*Penguin*" oozes. Mr. Sidebottom states that the late Mr. Thornhill had picked out over 12,000 specimens, and had commenced to arrange them on a scheme which he had devised but did not live to carry out. Personally, Mr. Earland said, he regretted that Mr. Sidebottom had not found time or opportunity to use the unique material which came into his possession at Mr. Thornhill's death, as a centre around which to build up a complete monograph of this beautiful genus. Perhaps he may yet find himself able to deal with this task. But, in any case, it is a matter for congratulation that Mr. Thornhill's work did not perish and disappear unrecognised on his death, as so often happens when a worker dies, but that his material has fallen into the hands of Mr. Sidebottom, whose beautiful drawings will make it accessible to all interested in the group.

One of the most noticeable features of this group is the very large proportion of decorated forms. Many of the recognised species are very hard to identify on account of the almost infinite variety and variation of the minute spines and markings which characterise them. The object of such markings seems to be quite beyond speculation. They are quite invisible to the naked eye, and, unlike the markings of diatoms, do not appear to have any physiological significance. Mr. Earland thought the Club was to be congratulated on obtaining two such notable papers for publication in its Journal.

The President said that he was afraid he was not able to throw any light on the significance of the markings and characters of the kind Mr. Earland had mentioned. He thought they were quite inexplicable at present. It must be admitted that a great number of specific characters are not due to adaptations, and one may go further and ask how far the origin of species is affected by natural selection. What proportion of specific characters are adaptations at all? How often can one say that any character is really adaptive? He would like the opinion of some of the Club workers. Would Mr. Rousselet, for instance, say that all the specific characters of rotifers were adaptations? He would not say an organism was not adapted to its environment, but he would say that many organisms exhibit a whole host of characters not due to environment. They could not explain everything as due to natural selection. Darwin laid great stress on "The Origin of Species by Means of Natural Selection," and thought that specific characters came first, and then natural selection came in and weeded out any not suited to the environment.

Mr. C. F. Rousselet thought it was impossible to determine what characters were really adaptive in the Rotifera.

Mr. D. Bryce said natural selection did not apply to his Bdelloids, as they were all females. It was a real case of survival of the fittest. Occasionally a specific character must be an absolute hindrance, and, in the case of long spines, must sometimes be positively dangerous.

The President said it was very difficult to put oneself in the position of, for instance, a sponge. But take the case, say, of a small protuberance on a spicule, which spicule is quite surrounded and embedded in the general protoplasmic mass of the animal, and then assume another similar spicule which is without such protuberance. It is not possible to conceive that either the presence or absence of such a minute speck of silica could be of any use to the individual, and yet such a difference is often absolutely characteristic of a species. We have had instanced this evening elaborate decoration and markings on Foraminifera. These animals certainly cannot appreciate them visually, as they have no organs of vision; and, again, in life the markings would be concealed under the usual gelatinous mass of exterior protoplasm. The markings are so minute that it is quite impossible

that the organisms could be cognisant of their existence in any way. The markings are of such a nature as to be quite without use to the organism, and we may take it that the possession of one particular pattern is of just as much, or little, use to the organism as the possession of any other pattern. Have we any right to say that any one of the patterns is an adaptation?

Mr. A. E. Hilton cited the case of the Mycetozoa, where the specific nomenclature is based on minute markings on the capillitium. These markings are really the waste products of the protoplasm which is purifying itself in spore-formation. It is quite certain that the cause of the different markings must be in the protoplasm itself. The protoplasm of different species makes deposits in different shapes, and these must be largely dependent on the condition of the air, as regards temperature and moisture, at the times of spore-formation. The real seat of the difference lies in the protoplasm itself.

Mr. W. R. Traviss exhibited and described a simple apparatus, for use in pond-hunting, for collecting water from depths which cannot be reached with the usual dipping-tube and stick. It consisted of a light metal cylinder closed at one end. At the other a light frame is fixed in a sort of handle-shape. This frame serves as support to a stout metal rod, which is fastened at the other end centrally to the bottom of the cylinder. On the rod slides loosely, first, an easily fitting cap to the cylinder, and, next, several lead discs. A string is attached to the bottom of the cylinder—actually to an eye formed by bending the end of the central rod which is projecting outside. Another string is attached to the opposite end of the rod. In use the weight of the lead discs is so adjusted that they will take the cylinder down to the bottom, upside down and full of air, the contrivance being lowered by the string attached to the bottom, the other string hanging slack. On reaching the bottom, or, if desired, some particular depth which could be marked on the string, the second string is gently pulled, bringing the mouth of the cylinder away from the bottom, and permitting some of the contained air to escape. Two or three tugs at the string will allow all the air to rush out, and at the same time fill the cylinder with bottom-water. It will now be right side up, and the lead weights which carried it down will keep the loosely fitting lid in position as the apparatus is drawn up by the top string. Practically no

exchange of water takes place. Mr. Traviss also exhibited a very convenient and portable form of siphon-strainer.

Several members testified as to the efficiency of Mr. Traviss's apparatus, which he used at the last excursion of the Club (June 21st).

A paper "On a New Method of Measuring the Magnifying-power of a Microscope," communicated by Mr. E. M. Nelson, F.R.M.S., was read by Mr. J. Grundy.

After reading Mr. Nelson's paper, Mr. Grundy offered a few remarks of his own.

Mr. Grundy exhibited a modification of the photomicrographic camera projection method. A light cardboard tube of about $2\frac{1}{2}$ in. diameter and about 12 in. in length fits loosely over the eye-piece; the other end is supported by a clamp-stand. (The microscope may be in any position; inclined is most convenient.) At a distance of about 10 in. from the lower end a circle of fine ground-glass is fitted. This is carried in a "draw-tube," permitting correction for the position of the Ramsden disc for various eye-pieces or for different tube-lengths. If a micrometer is placed on the stage the projected image may be observed on the ground-glass, and the divisions gauged with dividers, and compared directly with an ordinary rule. Mr. Grundy also exhibited microscopes fitted with Beale's neutral-tint camera-lucida, Ashe's modification of Beale's form, and a Wollaston model.

The President said they were much indebted to Mr. Nelson for his paper, and to Mr. Grundy for reading it. He had himself very often to make microscopical measurements, and though no doubt the method described was very good in theory he did not know how it would work out in practice as compared with the very simple method which he was accustomed to adopt—namely, by drawing the object with a Beale's camera, and then in the same way drawing the micrometer scale when placed on the stage in place of the object. By applying these to one another he could measure a thing in a very short time, and did not see how he could possibly go wrong in so doing, although there might be a slight distortion caused by the eye-piece.

A cordial vote of thanks was accorded to Mr. Nelson for his useful paper, and to Mr. Grundy for the interesting way in which he had brought the paper before the Club.

OBITUARY NOTICE.

THE RIGHT HON. SIR FORD NORTH, P.C., F.R.S., F.R.M.S.

Born January 19th, 1830; *died October 12th*, 1913.

We regret to record the death of Sir Ford North, one of our well-known members. He died at his estate in Morayshire, in his eighty-fourth year. He was the son of a solicitor, and became a barrister practising in the Chancery Courts (1856). He was made a Q.C. in 1877, and afterwards a judge, at first in the Queen's Bench division (1881), and then in the Court of Chancery (1883). He was a Fellow of the Royal Society, and a well-known entomologist. He was elected a member of the Q.M.C. in June 1894, and in the same year F.R.M.S.; he was a member of our Committee in February 1899, and was one of our Vice-Presidents from February 1901. His unassuming and cordial manner and the interest he displayed in the objects exhibited by members produced a feeling of friendship towards him in all those who had the pleasure of meeting him, while his patience and experience in directing a meeting when he occupied the chair, as was frequently the case, made him a most valuable member of the Club, and one whose loss we all greatly regret.

THE PRESIDENT'S ADDRESS.

ORGANISMS AND ORIGINS.

By Prof. Arthur Dendy, D.Sc., F.R.S.

(*Delivered February 24th*, 1914.)

I have in my library a copy of a posthumous edition, published in 1732, of a remarkable work by John Ray, entitled "*Three Physico-Theological Discourses*, concerning I. The Primitive Chaos, and Creation of the World. II. The General Deluge, its Causes and Effects. III. The Dissolution of the World, and Future Conflagration." The second of these discourses contains a very long discussion on the origin of fossils, which begins as follows: "Another supposed Effect of the Flood, was a bringing up out of the Sea, and scattering all the Earth over, an innumerable Multitude of Shells and Shell-Fish; there being of these Shell-like Bodies, not only on lower Grounds and Hillocks, but upon the highest Mountains, the *Apennine* and *Alps* themselves. A supposed Effect, I say, because it is not yet agreed among the Learned, whether these Bodies, formerly called *petrified Shells*, but now-a-days passing by the Name of *formed Stones*, be original Productions of Nature, formed in imitation of the Shells of Fishes; or the real Shells themselves, either remaining still entire and uncorrupt, or petrified and turned into Stone, or, at least, Stones cast in some Animal Mold. Both Parts have strong Arguments and Patrons. I shall not balance Authorities, but only consider and weigh Arguments."

In the end Ray pronounces in favour of the view that the fossils are real shells and not mere sports of nature, but he adopts a most singular hypothesis as to how they found their way into their present situations. It is only fair to add that this hypothesis did not originate with him, but was the offspring of the fertile brain of his "learned and ingenious Friend, Mr. *Edward Lhwyd*."*

* I am indebted to my friend, Mr. A. W. Sheppard, the Editor of this Journal, for the information that Mr. Edward Lhwyd, M.A., F.R.S., was keeper of the Ashmolean Museum from 1690 to 1709, and published a catalogue of fossils in 1699.

Mr. Lhwyd appears to have been much impressed by the alleged fact that marine shells are sometimes generated in the bodies of men and other animals, though at the present day it is difficult enough to understand how such statements could ever have gained credence. He observes: "For to me it appears a far less Wonder, that Shells and other Marine Bodies should be produc'd in the Bowels of the Earth, than their Production in the Bodies of Men or Animals at Land. And that they have been so found, is sufficiently attested, both by Ancient and Modern Authors, of a Credit and Character beyond all Exception." Obviously the universal deluge could hardly be held responsible for the occurrence of marine shells in human bodies, and therefore why hold it responsible for the occurrence of similar things in the bowels of the earth?

The ingenious Mr. Lhwyd proceeds as follows: "I therefore humbly offer to your Consideration, some Conjectures I have of late Years entertain'd concerning the Causes, Origine, and Use of these surprising *Phænomena*. I have, in short, imagin'd they might be partly owing to Fish Spawn received into the Chinks and other *Meatus's* of the Earth in the Water of the Deluge, and so be deriv'd (as the Water could make way) amongst the Shelves or Layers of Stone, Earth, &c. and have farther thought it worth our Enquiry, whether the Exhalations which are raised out of the Sea, and falling down in Rains, Fogs, &c. do water the Earth to the Depth here required, may not from the *Seminium*, or Spawn of Marine Animals, be so far impregnated with, as to the naked Eye invisible, *animalcula*, (and also with separate or distinct Parts of them) as to produce these Marine Bodies, which have so much excited our Admiration, and indeed baffled our Reasoning, throughout the Globe of the Earth. I imagin'd farther, that the like Origine might be ascribed to the Mineral Leaves and Branches, seeing we find that they are for the most part the Leaves of Ferns, and other *Capillaries*; and of Mosses and such like Plants, as are called less perfect; whose Seeds may be easily allow'd to be wash'd down by the Rain into the Depth here required."

You will note that the Deluge has not completely disappeared from the hypothesis after all, but we may gather from what follows that it has crept in rather by force of habit, and that the author really relies principally upon the clouds and rain for conveying

the "Seminium" into the crevices of the rocks where it is supposed to develop. Indeed, he accounts in this manner for the fact that so many of the fossil shells found in Great Britain belong to species not found in the adjacent seas. The "Seminium" has been brought from distant regions in the rain-clouds.

In order to make his argument more convincing, Mr. Lhwyd, who is quite aware of some of its weakest points, adopts the well-known method of answering possible critics in advance. "*First*," he says, "It will be questioned whether the supposed *Seminium* can penetrate the Pores of Stones." To this he replies "That it's manifest from Experience, upon which all solid Philosophy must be grounded, that the Spawn of Animals may insinuate itself into the Mass of Stone. And this plainly appears from Live Toads, found sometimes in the middle of Stones at Land, and those Shell-fish called *Pholades* at Sea." In other words, facts are facts, and there is no getting away from them. "*Secondly*, 'It will scarce seem credible' that such Bodies, having no life, should grow, especially when confined in so seemingly unnatural a Place as the Earth, &c." The answer to this is again supplied by the voice of authority, supplemented by an original observation on the part of the author which indicates clearly enough the amount of reliance that is to be placed upon his conclusions. "That's not so great a Wonder," he says, "as that Shells should be sometimes generated, and even grow, tho' they contain no Animals, within humane Bodies; and within the Mass of those thick Shells of our large *Tenby* Oysters, which I formerly mentioned to you, as first shown me by Mr. *William Cole* of *Bristol*, and have since observ'd myself. For we must grant, that the Earth, even in any Part of the Inland Country, is much fitter for their Reception and Augmentation than humane Bodies; especially, if we reflect, that when the *Spat* or *Seminium* here suppos'd meets with saline Moisture in the earth, living Animals are sometimes produced, as is before attested." And so on to ninthly and lastly.

Evidently, in the year 1698, when this was written, the problem of how the apple got into the dumpling had not yet been solved by the philosophers. It is a little surprising, however, that such views should have been accepted by so experienced an observer as John Ray, who has been called the Father of modern zoological science. Nevertheless, he

quotes them at length, and adds: "For my part (if my Opinion be considerable) I think that my learned Friend hath sufficiently proved that these Fossil-shells were not brought in by the universal Deluge. He hath made it also highly probable, that they might be originally formed in the Places where they are now found by a spermatick Principle, in like manner as he supposes. Why do I say probable? It is necessary that at least those, which are found in the *Viscera* and Glands of Animals, be thus formed; and if these, why not those found in the Earth? I shall say no more, but that those who are not satisfied with his Proofs, I wish they would but answer them." Thus even Ray, who was turned out of his Fellowship at Cambridge because he refused to make a declaration with regard to the Solemn League and Covenant demanded by the authorities, allowed himself to be completely enslaved by his own credulity with regard to unverified and, indeed, absurd statements as to the occurrence of marine shells in the bodies of land animals!

I suppose that Mr. Lhwyd's quaint hypothesis was almost the last of the many curious attempts that were made to explain the existence of fossils before our modern views on the subject came to be generally accepted. It affords an interesting illustration of the power of uncriticised authority to lead people astray. Unfortunately, however, we cannot do without authority in science. No man has either time or opportunity to prove all things for himself. Progress is rendered possible only by the accumulation of the labours of many workers, each relying upon his fellows. The only safeguard against error is the free exercise of our critical faculty and the due restraint of our natural credulity—the original sin of the scientific man.

Let us turn now to another hypothesis. In 1875 Prof. Huxley, in one of his extraordinarily stimulating essays,* discussed the relation which exists between the composition of the earth's crust and the organisms by which it has been populated. He points out that the great Swedish naturalist Linnæus, who was born in 1707, only two years after the death of Ray, had already enunciated the dictum that "fossils are not the children, but the parents of the rocks"—in other words, that rocks originate from

* "On Some of the Results of the Expedition of H.M.S. *Challenger*" 1875]. Collected Essays, vol. viii.

animals and not animals from rocks ("sic lapides ab animalibus, nec vice versa").

After discussing the character of the various deposits which form the floor of the ocean, Prof. Huxley remarks: "If the *Challenger* hypothesis, that the red clay is the residue left by dissolved *Foraminiferous* skeletons, is correct, then all these deposits alike would be directly, or indirectly, the product of living organisms. But just as a siliceous deposit may be metamorphosed into opal or quartzite, and chalk into marble, so known metamorphic agencies may metamorphose clay into schist, clay-slate, slate, gneiss, or even granite. And thus, by the agency of the lowest and simplest of organisms, our imaginary globe might be covered with strata, of all the chief kinds of rock of which the known crust of the earth is composed, of indefinite thickness and extent. . . .

"Accepting it provisionally, we arrive at the remarkable result that all the chief known constituents of the crust of the earth may have formed part of living bodies; that they may be the 'ash' of protoplasm."

The view that the red clay which forms the floor of the ocean at very great depths, and extends over an area of about fifty million square miles, is derived from the decay of the skeletons of Foraminifera from which the lime has been dissolved out, has not been substantiated by later investigations. According to Sir John Murray, the greatest authority on the subject, it has been formed chiefly by the disintegration of pumice and other volcanic ejecta.

It thus appears that the "ash of protoplasm" does not play nearly such an important part in the formation of the earth's crust as that suggested conditionally by Huxley.

My indefatigable friend, Mr. Kirkpatrick, however, has for some time been raking in all sorts of ashes for evidence of their origin, and has come to the conclusion that even in the most unlikely situations traces of simple organisms may still be found.* He has, I fear, as yet met with but little success in convincing his scientific colleagues of the correctness of his observations, but his results are certainly in close agreement with the conclusions arrived at by Linnæus and, provisionally, by Huxley. If these conclusions were correct we should have

* Vide *The Nummulosphere*, by R. Kirkpatrick. London, 1913.

to conceive of the solid crust of the earth as the result of a constant interchange of matter between the living and the dead, accompanied by physical and chemical processes of endless complexity. We might even think of it as a huge composite organism, alive only at the surface, but built up on the waste products of its own collective metabolism, like a world-embracing coral reef. I fear, however, that such a conception would be more picturesque than accurate.

Even if we accepted such a hypothesis we should, of course, have to remember that such a state of affairs could only have arisen through a slow and gradual process of evolution. Whether this process occupied a hundred million or a thousand million years would be a matter of comparatively small importance. It would be enough for our present purposes to recognise that it must have had a beginning at some extremely remote period of geological time, when the crust of the earth could not by any possibility have been composed of the detritus of living things.

It is generally admitted that there are only two possibilities with regard to the origin of terrestrial organisms. Either they must have been imported from some other planet in the form of germs, or they must have developed on the earth's surface from inorganic materials that formed part of the earth itself. Either event could only have taken place after the earth had cooled sufficiently to permit of the existence of those peculiarly unstable colloidal compounds of which living bodies are composed.

The first hypothesis has, as you are aware, received the support of no less eminent a man of science than the late Lord Kelvin, who believed it possible that the germs of living organisms might have been brought to the earth by meteorites. The chief objection to this view appears to be the difficulty of believing that any organism could withstand the heat generated by the friction of the meteorite with the earth's atmosphere.

A modification of the same hypothesis, sometimes known as the Theory of Panspermia, is maintained by Svante Arrhenius and others. According to this theory, numerous living germs of extremely minute size occur scattered through space, derived from various planets upon which life is supposed to exist, though at present we have no proof whatever that life does exist upon any planet except the earth itself. The nature of

these invisible germs is enigmatical in the highest degree. They are supposed to be propelled through space by the pressure of the radiant energy streaming from the sun—and it has indeed been demonstrated that very minute particles can be propelled in this way by rays of light. It has been objected to this view that no organisms could withstand the intense cold of interplanetary space, but we know that living organisms withstand low temperatures much better than they withstand high ones, and there appears to be no known minimum at which all life is necessarily destroyed. A more serious objection is to be found in what is known of the fatal effects of ultra-violet light rays upon micro-organisms. At the surface of the earth such organisms are to a large extent screened from the effects of these rays by the earth's atmosphere, but this would not be the case in interplanetary space.

Even if we were able to prove that living organisms first reached the earth from some other planet, however, it would not help us in the least to understand how they first originated. Such a hypothesis can only serve to remove the scene of action from the earth to some unknown sphere where the investigation of the problem is altogether beyond our reach. We may just as well assume at once that the first terrestrial organisms were generated *in situ* upon the earth itself and endeavour to find out how such generation may have occurred.

This brings us to our second alternative, which we may speak of as the hypothesis of spontaneous generation, or, if we prefer Huxley's term, abiogenesis. The discussion of this question has unfortunately been greatly prejudiced by the hasty conclusions of various observers who from time to time have announced that they have actually witnessed the production of living organisms from not-living matter, a claim which has been repeated at intervals ever since people began to speculate on such subjects, but which no one has yet succeeded in substantiating. I shall refer presently to the latest efforts in this direction, but in the meantime we must carefully bear in mind that the sudden appearance of recognisable organisms where none previously existed, and in situations to which no living things can have gained access, is a very different thing from the gradual evolution of living matter from inorganic substances by slow and imperceptible steps, which are at first purely chemical and physical in

nature but gradually assume a character which distinguishes them more or less from ordinary physical and chemical processes and perhaps justifies us in speaking of them as vital.

That there should be perfect continuity between not-living and living matter on the one hand, and between physico-chemical and vital processes on the other, is clearly demanded by the doctrine of evolution. Moreover we know that, at the present day, inorganic matter is constantly being converted into living protoplasm, though only by the peculiar organising activities of living bodies. All organisms assimilate materials derived from their environment in order to build up their own bodies, and it is largely this power of assimilation that distinguishes them from bodies that are not alive. During life the organism conquers its environment and appropriates such portions of it as it requires. Death is the conquest of the organism by the environment, accompanied by re-annexation on the part of the inorganic world of all that the organism had appropriated during its lifetime.

The chemist has no difficulty in analysing the complex colloidal constituents of dead organisms into a descending series of less and less complex substances, ending with the so-called elements themselves. He has also, to a very great extent, accomplished the reverse process, and has already carried his constructive operations as far as the synthesis of polypeptides, from which point to the proteids themselves is but another step. He has no right to assume, however, that when he has actually taken this step and, further, mixed his proteids with the other substances known to occur in living protoplasm, he will have produced anything that is actually endowed with life. We may even say, without much exaggeration, that the chemist, as such, has no knowledge of protoplasm at all, for it is impossible to analyse protoplasm while it is alive, and as soon as you kill it it ceases to be protoplasm.

Even the simplest living things known to us behave in a manner which cannot, at any rate in the present state of our knowledge, be explained entirely in terms of chemistry and physics. The living organism itself plays the part of the chemist and the physicist, and we cannot explain the chemist or physicist in terms of the chemical and physical operations which he performs in his laboratory. Out of a multitude of possibilities the living organism selects those materials and those modes of action

which are consonant with its requirements as a living organism, and its power of meeting emergencies as they arise is the measure of its power to survive. Moreover, it is able to profit by experience and to learn how best to overcome the difficulties presented by its environment. This being so, we are justified in maintaining that even the simplest living thing is endowed with a certain degree of intelligence, for intelligence is nothing but the power of learning by experience how to perform purposive acts.

We are not obliged, however, to suppose that the property which distinguishes the living from the not-living—intelligence, vitality, or whatever we choose to term it—came into existence suddenly. It is more in accord with our experience in other directions to believe that it arose by imperceptible degrees, *pari passu* with the evolution of organic from inorganic matter. This, however, must not be taken to imply that there is no essential difference between living and not-living bodies, either in structure or behaviour. We might with equal justice say that, because water is a compound of oxygen and hydrogen, there is no essential difference between water and a mixture of these two gases. We are told that to speak of the aquosity of water is meaningless pedantry, and that to speak of the vitality of living organisms is no less so. Of course, if such phrases are offered as explanations of phenomena, they are entirely valueless; but if used merely as a kind of shorthand expression of the fact that water and living organisms possess certain properties which distinguish them respectively from all other bodies, I see no more harm in them than in any other technical descriptive terms. In neither case can we supply a final explanation of the phenomena to which we refer.

Every stage in the evolution of matter is accompanied by the development of new properties or qualities which require the use of new descriptive terms. As to the so-called forces which lie behind these properties we know nothing. We can only classify them, as a matter of convenience, according to the effects which they produce. We speak of the force of chemical affinity, of the force of gravity, of electro-magnetic force, and so on; and if we choose to express our conviction that none of the so-called chemical and physical forces are adequate to explain all the phenomena of life, there is no logical reason why we should not,

as a matter of mere convenience, speak of vital forces also. Indeed, it appears to me more in accord with scientific method to do this than to ignore the existence of such characteristic vital phenomena as our own consciousness and intelligence or leave them to be explained by supernaturalism.

After all, the quarrel between the vitalist and the mechanist is chiefly over mere terminology. The vitalist knows perfectly well that the organism may to a very large extent be looked upon as a machine in which chemical and physical processes are utilised, and the mechanist knows equally well that he cannot hope to explain his own consciousness, and his own intelligent action, in terms of chemistry and physics. If we recognise these two facts it is a matter of comparatively small importance to decide in what terms the unknown factors can best be described.

At any rate I see no reason why vitalists and mechanists should not agree that living organisms first arose, either on our own planet or elsewhere, by means of a complex process of physico-chemical synthesis, in which the electron, the atom, the molecule, the colloidal multi-molecule and the simplest protoplasmic unit, may be taken as representing the chief stages. This at any rate is what we should expect from the study of those analytical and synthetical processes with which the bio-chemist has familiarised us, and from what we know of the process of evolution in general.

What may be the nature of the simplest protoplasmic unit is a question still under discussion. That it is not what we commonly call a cell seems certain, for a cell has a complex structure which must have been preceded by something very much simpler. The differentiation into cytoplasm and nucleus, and, above all, the extraordinarily complex phenomena of mitotic division, which are observable in nearly all cases where a distinct nucleus is present, can only have been attained as the result of a long process of evolution. The existence of the Bacteria, in which, although both cytoplasm and chromatin may be present, there is still no properly defined nucleus, perhaps indicates one phylogenetic stage through which the fully developed cell may have passed.

Possibly few biologists of the present day conceive of the most primitive organisms as relatively large unnucleated masses of structureless protoplasm, such as some of Haeckel's famous Monera were supposed to be. "The entire body of these

Monera," says Haeckel, "is throughout life nothing more than a motile lump of slime without constant form, a small living bit of an albuminoid carbon compound. We agree that this homogeneous mass possesses a very complex minute molecular structure; but this is not anatomically or microscopically demonstrable. Simpler, less perfect organisms are not thinkable." *

Recent researches, unfortunately, tend to throw considerable doubt upon the existence of such Monera. It has been pointed out that the failure to recognise a nucleus may have been due to the imperfections of microscopical technique at the time when the organisms in question were described. Even some of the Bacteria, which Haeckel regarded as Monera and which are amongst the smallest recognisable organisms, are now known, as we have just seen, to exhibit well-marked differentiations in their protoplasm, and many of the supposed "cytodes" or unnucleated cells, have already been shown to possess a nucleus. With regard to others the matter must be regarded as still *sub judice*.

Haeckel himself, it must be remembered, recognised the fact that his Monera must be composed of ultra-microscopic molecules or groups of molecules, which he spoke of as Plastidules or Micellae, the latter term having been coined by Naegeli.

It is these ultra-microscopic and indeed purely hypothetical particles of colloidal proteid that the modern biologist is inclined to regard as representing the most primitive living organisms, and Weismann has gone so far as to assign to them a definite place in our scheme of classification, proposing for their reception the so-called family Biophoridae and identifying them with the biophors or ultimate vital units of his well-known theory of heredity.

It has further been pointed out that such minute particles of living matter, far smaller than the most minute Bacteria, may be arising all around us by so-called spontaneous generation at the present day, without our being able to recognise the fact. It is only when, in the course of evolution, they had become aggregated in relatively large masses, that we could hope to see them even with the highest powers of our microscopes. The justice of this view might, however, fairly be questioned. When chemical molecules arise in our laboratories by combination of atoms or of

* Translated from Haeckel's "Schöpfungsgeschichte," Edition 9 (1898), p. 165.

simpler molecules, they usually present themselves to us in aggregates which are large enough to be at once recognisable, and one would naturally suppose the same to be true of the multi-molecules, biophors, or whatever we like to call them, of which living matter consists. As a matter of fact, however, the chief objection that I can see to the Monera theory is the almost ultra-microscopical size of the simplest organisms actually known to us. Indeed, if we take into account the so-called filter-passers, or Chlamydozoa, which are believed to be the germs of certain diseases, but most of which we know only by inference, we are justified in saying that the simplest known organisms are actually ultra-microscopic.

It seems impossible to obtain any precise information as to the size of the smallest particles that can be seen with the microscope. Since this address was delivered, Dr. Spitta has been kind enough to inform me that he has been able to see and photograph a particle only 1/97,000th of an inch in diameter, and it will be remembered that at a recent meeting of the Club Mr. Brown claimed to have seen in the frustule of a diatom a pore the diameter of which he estimated at 1/200,000th of an inch. As the filter-passing organisms are ultra-microscopic, they must be smaller than this. Indeed, most of them have never yet been seen even with the aid of the ultra-microscope, which, by a special method of illumination, enables us to recognise the presence of particles having a diameter of certainly not more than 1/2,500,000th of an inch and possibly a good deal less, though such particles cannot be seen at all in the ordinary way by transmitted light.

It is only by inoculation experiments that we can prove the existence of these ultra-microscopic parasites. Thus we are told that if even so small a quantity as 0·005 of a cubic millimetre of lymph from an animal suffering from foot and mouth disease be inoculated into a healthy calf, the latter will in due course contract the same disease, although the lymph, so far as microscopic examination enables us to judge, is entirely free from organisms.

Yellow fever, cattle plague, rabies and many other diseases are believed to be caused by ultra-microscopic parasites. That such diseases are due to living organisms and not to lifeless toxins is indicated sufficiently clearly by the fact that a period of incubation always follows infection, during which the poisonous matter

increases in amount until there is enough to produce its deadly effects, when the characteristic symptoms of disease manifest themselves in the patient.

Buckmaster considers that most of the filterable parasites are Bacteria, but as we know nothing of their structure it seems a little premature to include them in any group which is based upon morphological characters. They might be included in Weismann's hypothetical Biophoridae, although, from the point of view of the higher organisms, "death-carriers" would certainly be a more appropriate name for them than "life-carriers."

Inasmuch as all the known filter-passing organisms are parasitic, it might be argued that their existence implies the pre-existence of higher organisms, and that therefore they cannot be regarded as themselves representing the most primitive living things. Such an argument would, of course, be entirely fallacious. It so happens that at the present time the only means we have of recognising the most minute of these organisms is by their effects upon other organisms. There may be hosts of ultra-microscopic organisms living freely on the earth's surface which have no recognisable effects upon the higher plants and animals, and of whose existence we therefore remain in complete ignorance. This would be quite in harmony with what we know of the microscopically visible Bacteria. Some of these live freely in the soil and are able to feed upon purely inorganic substances, while others are far more familiar to us on account of their influence, whether beneficial or disastrous, either upon ourselves or upon other organisms in which we happen to be interested.

Your late President, Prof. E. A. Minchin, who speaks with great authority on such subjects, in his last address to the Club, devoted some time to the consideration of the question whether the extremely minute organisms which we have been discussing consist of cytoplasm or chromatin, and pronounced in favour of the latter alternative. For my own part I must confess that I prefer the view that at this stage of evolution the distinction between cytoplasm and chromatin has not yet arisen, a view which, as Prof. Minchin pointed out, is in harmony with the hypothesis of the evolution of living matter from inorganic substances on the earth rather than with that of its importation from some other planet.

It follows inevitably from the above considerations that the frequent failure of experimenters to demonstrate the occurrence of spontaneous generation cannot be regarded as proof that it never takes place even at the present day; much less as proof that it has never taken place in the past.

The classical experiments of Pasteur, Tyndall and other observers of the nineteenth century, so far as they related to spontaneous generation, seem to have been for the most part confined to the problems involved in the occurrence of organisms in organic infusions, such infusions being the media in which most of the known micro-organisms naturally occur and from which they derive their food-supplies. As a result of such experiments it is generally believed to have been demonstrated clearly enough that if adequate measures are taken in the first place to sterilise the culture media by heat, and in the second place to prevent the access of living germs after sterilisation has been effected, such infusions may be kept for an indefinite time without any organisms making their appearance in them, and, consequently, without undergoing putrefaction. It is also, I believe, generally supposed, though with little justification, that this conclusion applies to all culture media whatever, whether organic or inorganic.

One observer, however, Dr. Charlton Bastian, whose earlier experiments were contemporary with those of Pasteur and Tyndall, and who has recently been again engaged in similar investigations, has consistently maintained a different view. His earlier experiments, like those of other observers, were conducted with organic infusions, or with artificial nutrient solutions such as ammonium tartrate or other salts of ammonia. The positive conclusions arrived at by experiments with organic culture media may be considered to have been completely negatived by the general experience of bacteriologists during the subsequent forty years.

With regard to the origin of living things from the inorganic world, however, the negative results obtained by properly conducted experiments with organic infusions are of comparatively little value. If spontaneous generation takes place at all at the present day it probably takes place as it must have done at some time in the past, when no organic bodies existed to supply food for the first living things. In other words, we

should not expect to be able to observe spontaneous generation in infusions of organic matter, but should conduct our experiments with purely inorganic substances.

Dr. Bastian's *a priori* position is a very strong one. If spontaneous generation took place once upon the earth's surface there is no known reason why it should not take place to-day, while the actual existence of countless hosts of extremely primitive organisms alongside the most highly finished products of organic evolution certainly seems to support the view that such primitive forms are constantly arising from inorganic constituents and emerging from the obscurity of their birth only when they have reached a stage of evolution at which they are capable of appealing directly or indirectly to the human senses.

Dr. Bastian employed for some of his recent experiments * a very dilute solution of sodium silicate, to which was added either a minute quantity of pernitrate of iron, or a small quantity of phosphoric acid and ammonium phosphate. He points out, however, that the sodium silicate is a variable commercial product and attributes to this fact certain otherwise unaccountable variations in the results obtained. The experiments were therefore repeated with pure colloidal silica in place of the sodium silicate, and positive results were again secured.

The method of procedure is as follows. The solution to be experimented upon is hermetically sealed up in a glass tube and heated to about 130° C. for ten minutes or more. After the lapse of a few weeks, or in some cases months, during which time the sealed tubes have been exposed to ordinary atmospheric conditions, they are found to contain living organisms, Torulae, Bacteria and even moulds being present in varying quantities. Dr. Bastian claims that these organisms have arisen in the tubes by spontaneous generation, or, as he terms it, *Archebiosis*. He supposes that the living matter probably originated in the first place in the form of ultra-microscopic particles, but maintains that in the course of a few weeks or months these particles developed into the organisms finally found.

To a certain extent these results are, as I have already pointed out, in accord with purely *a priori* expectations, but in other respects they appear improbable to the last degree. Most of the

* For a full account of these experiments the reader is referred to Dr. Bastian's recent book on *The Origin of Life*, 2nd Edition, 1913.

organisms produced are of well-known types, and one of the moulds formed appears to be a Penicillium producing spores in the ordinary way. I must confess that I myself find it impossible to believe without much stronger evidence that such comparatively highly organised beings can have been evolved so rapidly from ultra-microscopic germs. We are accustomed to think of evolution as a very slow and gradual process, and we know that Bacteria, Torulae and moulds may be cultivated for an indefinite period without undergoing any recognisable change; indeed many industries, such as brewing, wine-making and cheese-making, depend for their very existence upon this fact. May we suppose that all these organisms have reached the limits of their evolution? If so we have the answer to the question, why have they remained stationary while other organisms have developed into the higher forms of plants and animals? If, however, we are asked to believe that the Bacteria and Torulae are stages in the evolution of the moulds, why does not this transformation manifest itself in our everyday experience? Dr. Bastian himself, it should be observed, is a convinced upholder of the doctrine of heterogenesis, or the sudden appearance of one kind of organism as the offspring of another, but it may be doubted whether any other living biologist holds similar views.

Again, are we to believe that such organisms arise in nature under many different conditions and from many different mixtures of chemical compounds, or are we to believe that Dr. Bastian has accidentally, and almost at the first attempt, hit upon just the right materials and the right conditions for the production of well-known living things? His own observations, if correct, show that the experimental solutions may be varied within wide limits, but this is hardly what we should expect if the origin of living things is to be regarded as a mere stage in a series of chemical and physical processes. Another criticism of these results may be based upon the fact that the materials employed do not (unless accidentally) contain all the necessary ingredients of protoplasm. Carbon is apparently entirely wanting, and we must either suppose that it is accidentally present in minute but sufficient quantities as an impurity, or else that it can, as Dr. Bastian actually suggests, be replaced, to a greater or less extent, by silica in his organisms. It has

been suggested that the colloidal character of the silica employed is especially favourable to the evolution of living matter, but unless the organisms are largely composed of silica, which is highly improbable, it is difficult to see exactly what the colloidal silica has got to do with their origin, unless, indeed, it may be supposed to act as a catalytic agent.

Altogether I think we may fairly say that the acceptance of Dr. Bastian's results would involve us in so many difficulties that it is preferable at present to believe that there has been some error in his mode of procedure, some unsuspected loophole through which contamination of his preparations has taken place.*

The whole problem looks surprisingly like a modern version of the old story with which we started. The question "What was the origin of the fossils in the rocks?" is replaced by the question "What was the origin of the organisms in the glass tubes?" We have seen how, in the former case, certain statements, made apparently in perfectly good faith, led to entirely wrong and absurd conclusions. We are all agreed now as to how the fossils got into the rocks, but I am not aware that anyone has ever succeeded in explaining the mystery of how the marine shells got into the human body, or even how the toads got into the stones in which they were alleged to have been found. No one, however, whose opinion is worth considering, believes that they were generated there. All are agreed that there must have been something wrong with the original statements, and there we must be content to leave it. It is doubtless premature to say that Dr. Bastian's organisms are merely toads in stones, but I do not see much to choose between the difficulties of explanation in the two cases. The decision must be left to the future, and in the meantime we may console ourselves with the reflection that science

* Since this address was written Dr. Bastian has published a lengthy communication in *Nature* (January 22nd, 1914) in which he tells us that his results have been confirmed by four other observers, two in America and two in France. The American observers say, however, "We have no suggestion to make other than your interpretation, and, indeed, we desire to be entirely non-committal as yet." Prof. Hewlett, the well-known bacteriologist, writing at the same time, states that, although he has made similar experiments, he has not yet been able to confirm Dr. Bastian's results.

cannot be infallible, but can progress only by a process of natural selection, in the course of which one hypothesis replaces another in the struggle for existence. The buckets in which we draw up truth from the bottom of the well are very small and very leaky, and a good deal that is not truth finds its way into them before they reach the surface. Fortunately the impurities, even if they cannot be eliminated at once, sooner or later sink to the bottom and leave the water clear.

A CHANGER FOR USE WITH SUB-STAGE CONDENSERS.

By S. C. Akehurst, F.R.M.S.

Read October 28th, 1913.

Figs. 1 and 2.

Petrological microscopes have been fitted in various ways to arrange for a quick change of sub-stage condenser, and I have frequently felt the need of a similar method applied to a

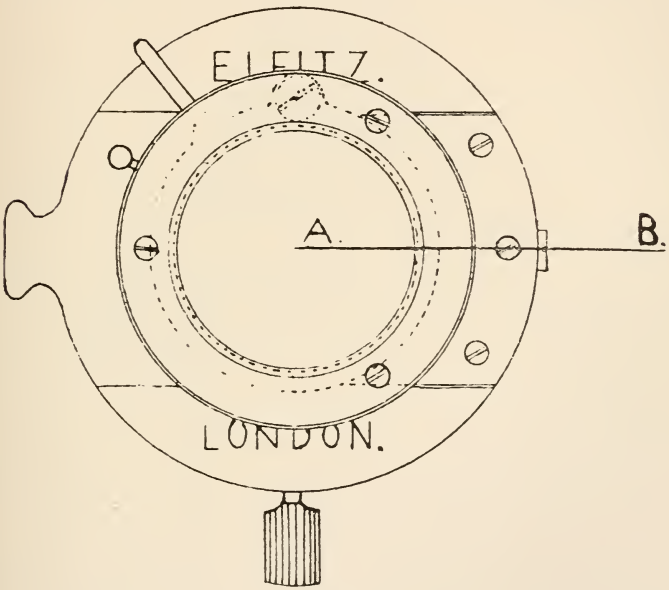


Fig 1.

biological microscope. I found the revolving nose-piece to carry three condensers did not work satisfactorily, therefore adapted the principle employed in the sliding objective changer to the sub-stage fitting, and found this enabled me to get an easy and rapid change of condensers.

The scheme consists of a metal slide $2\frac{1}{2} \times 1\frac{1}{2}$, with bevelled edges, on which the condenser is mounted, and, when necessary, a throw-out arm for stops, and an iris diaphragm. Two D-shaped

metal plates, the flat sides of which are set $1\frac{1}{2}$ inch apart, form a groove for the slide to work in. These plates are screwed to a metal collar, the diameter of which is such as to allow the slide-condenser changer to be fitted to any microscope that has a sub-stage made to the R.M.S. gauge. Fig. 1 shows a plan of the slide changer in position, while fig. 2 gives a sectional elevation along the line A B, fig. 1. When three, or more, condensers are used it is desirable to have each mounted on a separate slide; but when only two condensers are used, one slide may be sufficient, as the optical parts can be made interchangeable.

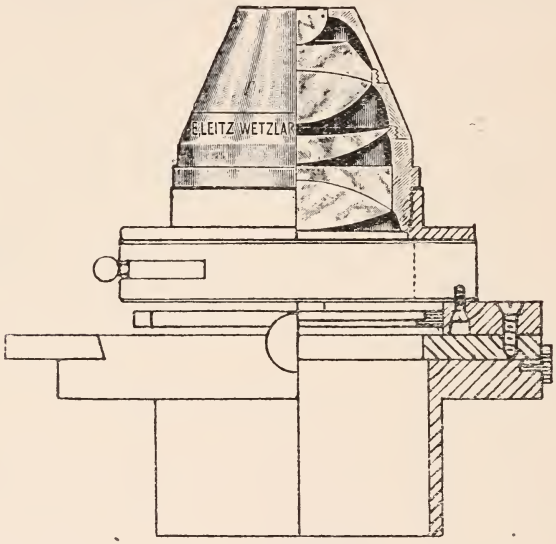


FIG. 2.

When the slide with condenser has been pushed home, a screw, working through one of the plates, holds this firmly in position.

This changer does away with the necessity of a throw-out sub-stage, and any variation of centrality in the condenser can be adjusted by the centring screws in the regular way.

To rack down the sub-stage fitting, withdraw and insert a new slide, are all the movements that are required to obtain a change of condenser, and this can be effected as readily as a change of objective on a revolving nose-piece.

A TRAP FOR FREE-SWIMMING ORGANISMS.

By S. C. Akehurst, F.R.M.S.

(*Read October 28th*, 1913.)

Fig. 3.

Simply stated this is an arrangement which cuts off the retreat of the creatures after they have been attracted into a small receptacle by light.

The first trap I used was made of glass—in two pieces. The top is funnel-shaped, and holds about 5 ounces of water. This is attached to a horizontally-placed cylinder, 1 inch in diameter, and $1\frac{3}{4}$ inch long—the whole being mounted on a stem and foot.

Into the cylinder is fitted a glass spigot, which has been ground in to avoid water passing. There is a hole at the bottom of the funnel flask which allows free access of the water to a small well in the glass spigot.

When the trap is working, this well opens immediately under the hole at the bottom of the flask, and into this the organisms can enter freely. When desiring to fix the catch, give the spigot a slight turn—the mouth of the well then presses against the side of the cylinder and the contents become locked in.

To set the trap, fill the flask with pond water, cover the entire funnel-shaped flask with some light-proof material, and direct all the light that can be gathered by a bull's-eye on to the cylinder which contains the glass spigot. Any swimming phototactic organism in the water will at once react and pass into the well, which is brightly illuminated—usually 10 to 15 minutes is sufficient to allow for this, but longer time can be given if necessary. Give the spigot half a turn, and, as already explained, this locks the creatures in the well. The water can then be poured off from the flask, the spigot withdrawn, and the rotifers—or whatever may have been trapped in the well—can be taken up with a pipette and transferred to the slide for examination.

After the first catch has been taken the trap can be set again and a second lot secured. Work can therefore be carried on without interruption or loss of time until all the water has been dealt with.

Should there be any sediment, this can be allowed to settle and then trapped off before any attempt is made to catch the organisms.

There is difficulty in obtaining this trap made in glass; I have therefore worked out another in metal (fig. 3). This consists of a round box, 1 inch in depth, $3\frac{1}{4}$ inches in diameter—the top and bottom slightly convex—mounted on a tripod. A hole in the bottom allows the water to pass through a short tube, which is in three sections, the first part metal, the second rubber and the third glass. A pinch-cock can be applied to the rubber connection, which will prevent water passing when the glass tube has been removed for examination of contents.

I have departed from the funnel shape—making the metal box to hold the water almost flat, which will allow any sediment to settle at the bottom. If the water is very muddy, a cork can be fitted into the outlet hole and left until the debris has settled —first filling the tube with clean pond water.

If the cork is carefully removed, very little, if any, dirt will pass down the tube. Should some slip by, this can be trapped off, the tube refilled with water, when a perfectly clear gathering can be secured.

A strainer is provided, to be used, when necessary, for removing

Fig 3.

larvae or any of the entomostraca. It is important, that as much light as possible should be concentrated on the glass tube.

To arrange for this a bi-convex lens $1\frac{1}{2}$ inch diameter, silvered on one side and mounted in a metal holder with a movable support allowing it to be tilted at an angle, is placed under the tube, light from a bull's-eye condenser is received by the lens and a bright beam passed up the tube. This method of transmitting the light is very effective, and the trap in consequence acts more rapidly and effectively than when the bull's-eye condenser only is employed. The lens—placed in position—is shown in the illustration.

AN IMPROVED FORM OF CHESHIRE'S APERTOMETER.

By Edward M. Nelson, F.R.M.S.

(*Exhibited and described by James Grundy, F.R.M.S., October 28th*, 1913.)

Fig. 4.

Of the value of Mr. Cheshire's form of Apertometer there can be no doubt. The aim of Mr. Nelson has been to enable the N.A. of an objective to be read on the Apertometer with greater ease and accuracy.

Distinctness and clearness of reading have been effected by

Fig. 4.

increasing the number of marked values of N.A. from 9 to 22, without the confusion that overcrowding of the lines would entail. To accomplish this, short arcs of circles are used instead of whole circles. A valuable property of these is the clear visibility of the ends or edges of the arcs; they are seen more distinctly than complete circles would be. The contrast between the white ground and the short black lines favours this.

The exterior edges of the arcs denote the N.A., and thus give most convenient, accurate and definite positions for reading.

The first or lowest marked value is 0·05 N.A., and the values increase by increments of 0·05 up to 0·5 N.A. From 0·5, the values increase by 0·033 up to 0·9 N.A.

The apparatus consists of an Apertometer diagram (fig. 4) printed on a small card about the same size as Mr. Cheshire's form, another card of explanations and instructions, a cubic inch of wood and a metal diaphragm with a hole not more than 1·25 mm. in diameter. Mr. Nelson lays some stress on the hole in the diaphragm being not more than 1·25 mm. in diameter. He says: "If the hole is larger than that, some objectives, especially low powers, will read a great deal too high. And accuracy is, relatively, more important with the small apertures, because—for example—an error of 0·01 or 0·02 will make a far greater percentage of difference than it would with, say, the N.A. of an oil-immersion objective. If 1·25 and 1·27 be compared with the N.A. 0·11 and 0·13 of a 3-inch objective, the actual difference between the two pairs of values is 0·02 in each case, but the percentage difference with the higher N.A. is only 1·6 as compared with 18 in the case of the low values."

In this connection, Mr. Nelson has made another important remark, namely, "The *working* aperture is larger than the correctly measured *true* aperture, so that low powers resolve more than they are entitled to theoretically. This is probably due to the practically enlarged aperture caused by the rolling motion of the eye from side to side."

It will also be noticed that the diaphragm to be used with the apertometer is made convex on one side, and if the convex side is put into the larger aperture of an eye-piece—or other—diaphragm, it rests steadily in position.

TWO SIMPLE APERTOMETERS FOR DRY LENSES.

By Frederic J. Cheshire, F.R.M.S.

(*Read October 28th*, 1913.)

Figs. 5 and 6.

In dealing with questions of apertometry it is very important to inquire, in the first place, as to what order of accuracy it is desirable to work. No useful purpose would be served by giving a carpenter a foot-rule, divided to hundredths of an inch, with which to measure the length of a plank. The measurement, if made to such an order of accuracy, would be useless and meaningless.

Prof. Abbe, in "Some Remarks on the Apertometer" (*Journal of the Roy. Mic. Soc.* 1880, p. 20), after stating that the error of measurement in his well-known apertometer is limited to about $\frac{1}{2}$ per cent., goes on to say that "an exactness of *reading* to this extent is evidently more than sufficient. An unavoidable amount of uncertainty resulting from the nature of the object, and many other sources of slight error, will always limit the real exactness of *observation* beyond 1 per cent. of the unit, different observers and different methods of equal reliability being supposed. In low powers slight variations in the length of the tube, in high powers slight alterations of the cover-adjustment, will admit of much greater difference than the error of reading will introduce. It should be observed that in high-angled objectives the aperture has not the same value for different colours, owing to the difference of focal length (or amplification), even in objectives, which are perfectly achromatic in the ordinary sense. In the case of very large angles, the aperture, angular or numerical, will be greater for the blue rays than for the red, generally by more than 1 per cent. Last, not least, there is no possible interest, either practical or scientific, appertaining to single degrees, or half

degrees, of aperture angles; for no microscopist in the world will be able to make out any difference in the performance of objectives as long as the numerical apertures do not differ by several per cent., other circumstances being equal."

"For these reasons I consider all attempts at very accurate measurements of this kind to be useless."

No one, probably, is likely to have the temerity to question the authority of Prof. Abbe on such a question as Apertometry, so that we can accept his limit of 1 per cent. with confidence.

Fig. 5 shows a plan of a form of apertometer for dry lenses which for simplicity in use and for the accuracy of its results probably leave nothing to be desired. A strip of vulcanite A * is so divided that the distance D of any line from the zero of the scale is given by the equation

$$D = 2 \triangle \tan (\sin^{-1} \text{N.A.})$$

set out in this Journal for April 1904 (Ser. 2, vol. ix. p. 1), in the article on "Abbe's Test of Aplanatism, etc." The graduations are marked with the corresponding N.A. values for a value of $\triangle$ equal to 25 mm. In use the apertometer is placed upon the stage and the object plane of the lens to be tested adjusted at a height of 25 mm. above the plane of the scale. The upper focal plane of the objective is then observed in any known way and the apertometer adjusted on the stage until the inner edge of the fixed white block B is seen on one edge of the objective opening. This adjustment effected, the sliding white block C is slid along the strip A until its inner edge is seen on the opposite edge of the objective opening to that on which the block B is just seen. The N.A. value found opposite to the inner edge of the block C on the scale is that of the lens tested.

The graduations from 0 to 0·9 N.A. proceed by steps of 0·02 and from 0·9 to 0·96 N.A. by steps of 0·01.

Fig. 6 shows a modification of the form of apertometer described in my original paper in 1904. I have substituted for the concentric circles there shown curved lines which project optically into the upper focal plane of the lens being tested as a number of equi-distant straight lines of equal thickness. The projected image of the apertometer scale is thus a simple linear

* The right-hand end is shown broken off.

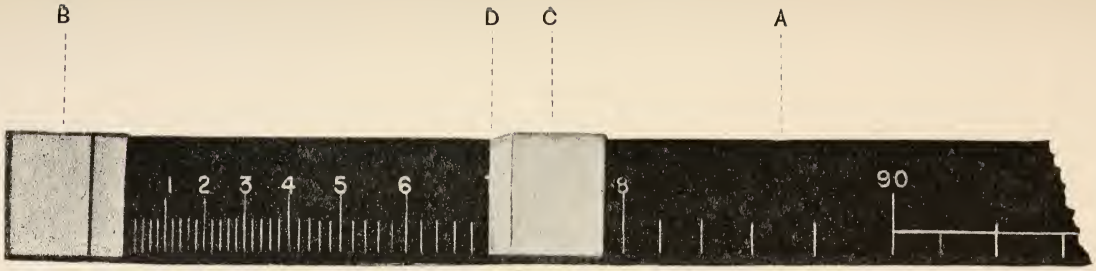


Fig. 5.

CHESHIRE'S APERTOMETER ($\triangle = 25$ mm.)

Fig. 6.

scale upon which N.A. values can be read directly. The scale runs from 0·0 to 0·9 N.A. by steps of 0·05, *i.e.* the divisions starting from the centre have the values 0, 0·05, 0·10, 0·15, 0·20, etc., of N.A.

The short curved lines of the scale should strictly be hyperbolas, but such curves are very difficult to draw accurately, and it was not until my son, Mr. R. W. Cheshire, suggested to me that they might be replaced by arcs of circles with curvatures equal to those of the corresponding hyperbolas at their vertices that the apertometer described became a practical construction.

I may, perhaps, be allowed to avail myself of this opportunity to say that in my opinion there are several objections to Mr. Nelson's form of the Apertometer which was introduced by me in 1904. These may be briefly indicated. In the first place, no advantage can result from the use of the outer edges of the lines, instead of the middles, as is usually done, as the part of the lines from which distances and therefore N.A.'s must be estimated by eye. Further, in Mr. Nelson's form the thickness of the lines varies in different parts of the diagram, and has no assigned or stated thickness in terms of N.A. This, I think, is a fatal defect, because when the thickness of a line has a N.A. value of 0·02, say, such thickness, especially when dealing with low-power lenses, provides an invaluable standard of reference when estimating by eye N.A. values intermediate to those represented on the scale.

In apertometers of the kind in question the further the subdivision of the scale is carried the greater must be the complexity of the image presented to the eye—the advantage of one is balanced by the disadvantage of the other. Possibly, however, most people would prefer the simplicity of a diagram with the larger divisions to the optical Hampton-Court-maze necessitated by the smaller ones.

A VARIATION OF CHESHIRE'S APERTOMETER.

By M. A. Ainslie, R.N., B.A., F.R.A.S.

(*Read October 28th*, 1913.)

Figs. 7 and 8.

Experience in the use of both the original forms of Cheshire's Apertometer, and the modification thereof recently introduced by Mr. E. M. Nelson, has revealed one or two difficulties in connection with the reading of the instrument—that is, if any accuracy in the second place of decimals is required—and the present instrument is an attempt at removing these.

The first difficulty is due to the fact that in Mr. Cheshire's instrument we have to interpolate or estimate between two divisions on a scale, one of which is not visible, being outside (apparently) the margin of the back lens of the objective. This renders the estimation of the second place of decimals in the N.A. uncertain, and although Mr. E. M. Nelson's modification of the original instrument is somewhat better in this respect—yet the very means adopted to improve the reading, namely, the introduction of a large number of additional circles—is likely to confuse the diagram and bewilder the observer.

In either the old form or the new of Cheshire's instrument, a count has to be made of concentric circles; a thing which, simple as it may seem, is peculiarly liable to confuse the eye; so that it is only after counting several times that one feels certain that the number is, say, eight and not seven. In the present instrument a totally different method of reading is adopted; the diagram is simplified, and the estimation of the second place of decimals is merely the estimation of the point where a spiral curve cuts the margin of the back lens of the objective, referred to two points, one on each side, where radial lines cut the same.

The instrument, which consists, in the form for dry lenses,

of a card diagram placed on the stage, is constructed as follows (fig. 7):

A series of radial lines are drawn from a common centre, making equal angles with one another; the precise number is immaterial, but it has been found convenient to divide the circle into sixteen equal parts. One of these (preferably that lying horizontally) is selected as a zero, and points are marked off along the others at distances equal to a constant length (usually 25 mm., or 1 inch) multiplied by the tangent of the semi-angle of aperture; *i.e.* the tangent of the angle whose sine is the numerical aperture. This is done for every 0·1 of N.A., and a spiral curve drawn through the points thus obtained; this

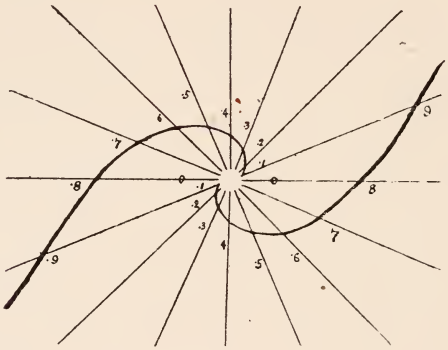


FIG. 7.

curve being repeated, turned through 180°. The curves are shown with fair accuracy in fig. 7.

The diagram is used precisely as the Cheshire Apertometer: either the objective is focused on the upper surface of a cube of wood as in the Cheshire instrument; or else a pinhole in the centre of the diagram is focused, and the body racked back 25 mm., or 1 in., this being measured easily enough with a scale. This latter method is preferable for objectives of high aperture. A low-power eye-piece is employed. On examining the Ramsden disc with a hand lens (a watch-maker's eye-glass does well) the appearance in fig. 8 is seen, and the method of estimating the value of the N.A is fairly obvious; we have only to start from the zero and count in the direction of the spiral,

0·1 for each radial line passed over; the second figure is found by estimating the position between two adjacent radial lines of the point where the spiral cuts the margin of the back lens. In fig. 8, for example, the N.A is about 0·73.

The procedure is the same with the form suited to immersion lenses; the upper surface of a plate of glass is focused, and the diagram is balsamed to the lower surface. It might be preferable to have 12 radial lines instead of 16, and read like a clock; this is a matter for experiment.

Of course the value of the radius vector of the curve for a diagram in optical contact with glass will not be quite the same as before; instead of $r = C \tan \phi$, where $\sin \phi = N$, we

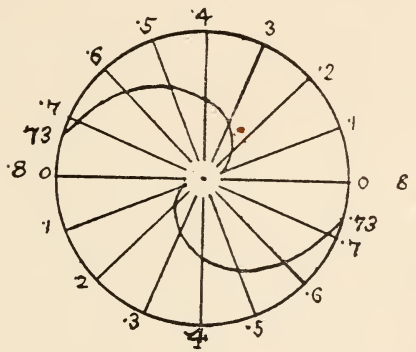


FIG. 8.

shall have $r = C \tan \phi'$ where $\mu \sin \phi' = N$; but the principle is the same.

The equation to the curve presents some interesting features; it is $r = C\frac{a\theta}{\sqrt{1 - a^2\theta^2}}$ where C is the distance of the diagram from the lower focal plane of the objective and a is a constant depending on μ and on the number of radial lines in the circle; for 16 radial lines, and $\mu = 1$ (dry form), $a = \frac{}{5\pi}$. The radius representing N.A. = 1·0 is obviously an asymptote to the curve; in the case of the glass form, N.A. = μ will be the asymptote.

It is of interest to note that the same curve will serve for any refractive index of the medium beneath which it is mounted; if

we change the refractive index from 1 to μ, we merely have to close up the radial lines in that ratio, leaving the curve unaltered. For instance, if we had 16 radii for the dry form we could use the same curve, but with 24 radii, for a plate of glass of $\mu = 1{\cdot}5$.

In practice the instrument proves of great utility, and very reliable and easily used. All that is necessary is to be accurate in centring; this is easily seen to be correct when the reading of each end of the spiral is the same.

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ON THE DISC-LIKE TERMINATION OF THE FLAGELLUM OF SOME EUGLENAE.

By James Burton.

(*Read November 25th*, 1913.)

About two years ago, one of our members—Mr. Ellis—was exhibiting here living *Euglena viridis*. During the evening the creatures, presumably affected by the light, heat and confinement of the life-slide, threw off their flagella; it was perhaps a preparatory step to encystment, or even to their death, under the unnatural conditions of their environment. In the field of the microscope there were numbers of these organs floating free, and in the case of many of them, if not quite the majority, they were terminated by what appeared to be a small disc or bulb. We were greatly interested in the phenomenon, and decided to investigate it. Mr. Ellis soon after wrote a letter to *The English Mechanic*, describing what he had seen, and inquiring if any one else had had a similar experience. There were no very definite answers, no one claiming to have noticed this occurrence before. In his letter he says:

"On turning on the one-sixth, something quite out of the ordinary—at least, to me—was seen in the shape of minute transparent discs, each with a long, thick, but motionless flagellum, and apparently associated with the resting Euglenae, around which they appeared most plentiful. For some time I was puzzled to account for these objects, until, noting the obvious similarity in length and thickness between their flagella and those of the motile Euglenae, I became convinced they were one and the same, they having been thrown off bodily by the exhausted Euglenae, and not retracted—as is usual, I understand." . . . "Now here comes the difficulty: What is the little disc to which the flagellum is attached? Is it the 'knob-like inflated distal extremity' of a flagellum belonging to 'an interesting local variety of *E. viridis*' described by a writer in *Science Gossip* for October 1879, and referred to by Saville-Kent on p. 382 of his 'Manual of the Infusoria,' and illustrated on

Pl. xx. fig. 29?" Saville-Kent says, in the paragraph referred to: "An interesting local variety of *E. viridis* has been recently described by Mr. M. H. Robson, of Newcastle-upon-Tyne, in which the distal extremity of the flagellum presents an inflated knob-like aspect, as shown at Pl. xx. fig. 29. Possibly such modification of this important organ represents a phase preliminary to its entire withdrawal, and antecedent to the entrance of the animalcule upon the encysted or resting stage."

In *Science Gossip* (1879) there are several letters about the phenomenon, one on p. 231 by Mr. Robson, with the original drawing from which Saville-Kent's figure is taken, and also two other forms of Euglenae with identical organs. Referring to them, Mr. Robson says: "These may be of interest, as I, at all events, have not met an observer who has previously noted this peculiarity." In a letter on p. 136 another writer mentions a case where in a large number of Euglenae "the flagellum was in each case bulbed." And he draws the singular conclusion that these were not true Euglenae, but suggests they may have been a larval form of the rotifer *Hydatina senta*. In a letter, p. 159, Mr. Robson writes of *E. viridis* and its "sucker bulb," and of the existence of "the bulb siphon, sucker, or whatever it is." On p. 256 there is a letter from Mr. George headed, "*E. viridis* and its bulbed flagellum," and he makes reference to the fact that "on one occasion, whilst closely watching the contortive movements of a full-grown specimen, I was much surprised to see the little animal 'bite off,' if I may so term it, the flagellum, which immediately floated away." It is clear at least from all this that observers a good many years ago saw the structure, and that it created a good deal of interest and some speculation as to the true interpretation of the appearance.

Now, to return to Mr. Ellis's question, "What is the little disc" attached to the distal end of the flagellum of some Euglenae? After some considerable attention to the subject, and observation of many examples, I have come to the conclusion that there is no disc, no bulb or sucker, or anything of the kind at the end of the flagellum. The appearance which has given rise to the idea can be correctly accounted for in another manner. I have often seen the disc since Mr. Ellis first called attention to it, but do not remember ever seeing it on a flagellum in active use by a healthy Euglena; in fact, it is almost impos-

sible to see the flagellum at all when the creature is in full vigour —it is then usually being lashed about, and is bent and twisted in all directions. It will be noticed that Mr. Ellis only claims to have seen the disc when, for some reason, the organ to which it was attached was thrown off.

He says: "Out of all the numberless motile Euglenae which were swimming about amongst their resting kindred, not one was seen with a flagellum having a knob at its free extremity."

Neither do I think any of the writers in *Science Gossip* distinctly claim to have seen it on a healthy, active animal. But when the flagellum is thrown off—"bitten off," as has been described—or when the Euglena is killed by a careful application of iodine, it is not at all infrequent, and I have seen it on specimens from many different localities.

It happened that since I thought of bringing the subject before you I was looking over, for quite another purpose, a slide of Euglenae mounted in April 1911. I there found several instances of discs still attached. Some creatures, and some Euglenae at all events, occasionally carry the flagellum stretched out rigidly in front, with a small portion of the distal end thrown into a coil or spiral form, usually rapidly moving. Now if the creature were killed with the organ in that position, or for any reason threw it off, it seems to me very probable that the coil—there might be but one turn in it—would present just the appearance we have had referred to as a disc or bulb, and that, consisting of protoplasm, it would be very likely to adhere where touching another part, and so retain its form as a circle. With the use of an immersion objective and careful illumination, it has seemed to me possible to make out a part of the circle as being thicker or darker than the rest, owing to the thread overlapping at that point. It must be remembered that we are dealing with a very small and very transparent structure, not easy to demonstrate correctly. Moreover, among the others, killed by iodine or mounted, it is easy to find specimens with the flagellum much twisted and thrown into "kinks." So that there are often small circles at the sides instead of at the end of the thread, and although these have just the same appearance as those at the end, I do not think any one would suggest that it is likely a disc or bulb would occur in such a situation, to say nothing of the improbability of there being more than one, and these often on

opposite sides. These would be put down at once as loops—or kinks—and I believe the so-called terminal disc or bulb is of the same nature, but it is more striking and more deceptive, owing solely to its position. When I told Mr. Ellis of the conclusion I had come to, he was at first disinclined to accept it, but afterwards, I think, did so fully. If I am right, the subject is merely an instance of correct observation but incorrect deduction from it—in fact, an error of interpretation, quite a well-known occurrence to microscopists! Perhaps, indeed, the matter would hardly justify particular reference to it, had not the figure and the note read appeared in Saville-Kent's Manual—a work whose value to us all gives it an importance and authority which must be my excuse.

ON THE MEASUREMENT OF THE INITIAL MAGNIFYING POWERS OF OBJECTIVES.

By Edward M. Nelson, F.R.M.S.

(*Read November 25th*, 1913.)

Fig 9.

The majority of microscopists only concern themselves with the total magnifying power of their microscopes, but some wishing to probe further into matters want to know the initial power of their objectives.

The initial magnifying power, m, of an objective is $\frac{10}{f}$, but the focal length (f) of an objective is a very difficult thing to measure directly. Usually it is found by an indirect method of measuring the magnifying power, for, as above, $\frac{10}{m} = f$.

Probably the best way of measuring the focal length by the indirect method is to project the image of a measured object, placed 100 inches from the stage, and to measure the diminished image at the focal point of the objective by means of a microscope, fitted with a screw micrometer; the magnification, m, thus obtained will give the focal length with great accuracy, for $f = \frac{100}{m + 2}$. As the numerator is 100, the result can be found in a reciprocal table, without the necessity of doing a division sum.

Simple as this seems, it is however a troublesome thing to do; but by the method here described the initial power, and hence the

equivalent focus of a microscope objective, can be quickly and easily measured.

The apparatus required is a stage micrometer and a screw micrometer with a positive eye-piece. With a tube of a length as described below, the interval of two divisions of the micrometer scale on the stage is read on the drum of the eye-piece, and this reading will be the initial magnifying power of the objective.

The only difficulty here is the determination of the proper tube length. The tube length is to be measured from the web in the eye-piece to the end of the nose-piece of the microscope.

The formula for the determination of the tube length is $15\sqrt{\frac{1}{p}+0{\cdot}335}$, where p is the nominal initial power. Example: The initial power of a half-inch is required. The nominal power of a half-inch is 20, which is p, then $15\sqrt{\frac{1}{20}+0{\cdot}335} = 15\sqrt{0{\cdot}385} = 15 \times 0{\cdot}62 = 9{\cdot}3$ inches tube length.

The tube must be drawn out until the web is 9·3 inches from the nose-piece, and, with the half-inch on the nose-piece, two $\frac{1}{1000}$ths of an inch divisions on the stage micrometer are spanned by the webs. The drum then is read, say, 22·4, and this is the initial power of that half-inch, without any further calculation; its focal length is $\frac{10}{22{\cdot}4}$ or 0·446 inch.

In case the nominal initial power is unknown, it is first determined with, say, a $9\frac{1}{2}$-inch tube, the value thus found is inserted in the equation and the measurement made again with the correct tube length. All powers of quarter-inch and less focus, all Zeiss's apochromats of whatever focus, and other makers' apochromats, require a 9-inch tube.

For lower powers the accompanying table, computed by the above formula, gives the necessary tube length.

It must be noted that it has been assumed that the screw micrometer with the positive eye-piece is an English one, with 50 threads to the inch, but if it is a Continental one, with a millimetre thread, a millimetre stage micrometer must be used, and the proper number of divisions measured. If it is found that the magnification is so high that two divisions cannot be spanned by the micrometer webs, then obviously one division is measured and the reading is doubled.*

TABLE.

O, objective; N, nominal power; T, tube length in inches.

O	N	T
	3	12·3
3	3·5	11·8
	4	11·5
	4·5	11·2
2	5	11·0
	5·5	10·8
	6	10·6
1½	7	10·4
	8	10·2
	9	10·0

O	N	T
1	10	9·9
¾	12	9·7
⅔	15	9·5
½	20	9·3
4/10	25	9·2
⅓	30	9·1
	35	9·05
¼	40	9·0

Let me again impress upon microscopists to measure, or get measured, the optical indices of their objectives. The optical index is $\frac{1000 \text{ N.A.}}{m}$. Photographers have the same thing in their $f/4$, $f/16$, etc. No photographer would think of paying as much for a lens of $f/16$ as he would for one, of similar focus and quality, of $f/4$; then why should a microscopist? A microscopist, for example,

* The foci of a large number of all sorts of microscope objectives, which had been previously accurately determined by the long method, were remeasured by this new short method; the results obtained were so satisfactory that now only the short method is used.

buys a $\frac{1}{10}$th objective of 0·65 N.A. Here an optical index of 26·0 is implied; when he gets home he measures it and finds it $\frac{1}{3}$rd of 0·55 N.A. with an optical index of only 18·3, or 30 per cent. less. This is not an exceptional case, but one which unfortunately exemplifies the usual practice. Messrs. Zeiss have for long set an excellent example by never sending out lenses below either their catalogued N.A. or shorter foci. I have measured scores of them and have found their optical indices often in excess, and seldom if ever in defect.

[The method of determining the focal length of an objective, by the indirect method from the magnifying power, may not be

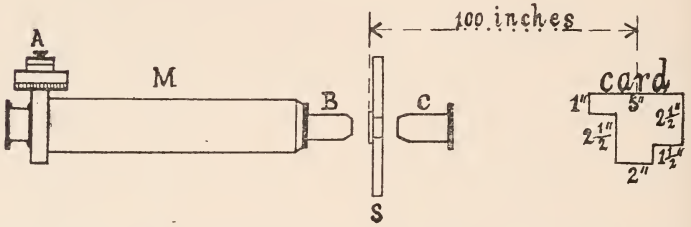


Fig 9.—Diagram to show Relative Positions of the Apparatus.

M—Microscope tube. B—Objective.
A—Screw micrometer. C—Objective to be measured, in substage.
S—Microscope stage and micrometer.

quite clear, hence the following particulars from notes received from Mr. Nelson may be useful. His own words are practically as follows: The microscope is placed horizontally; a low-power objective, 3, 2, or 1½ inch, according to circumstances, is placed in position; screw-micrometer eye-piece; the objective to be measured is placed in substage, with its front lens facing the stage. A card cut to the pattern as shown in figure (fig. 9) is fixed by means of a clip in front of the window: the card should be placed at the exact measured distance of one hundred inches from the stage of the microscope.

The stage micrometer is placed on the stage, and the constant of the screw-micrometer determined. The focus of the microscope is not to be disturbed, but, by means of substage focusing, the lens to be measured is racked up until the image of the card is sharply focused. Then one of the sides of the card is spanned by the webs of the eye-piece micrometer, and its size measured and the magnifying (or rather diminishing) power found: then $f = \frac{100}{m + 2}$.

Of course, the idea of the 5 inches is that the reading is doubled, and then $10 \div x$ (say), gives the magnification, m, which can be found from reciprocal tables, as well as the value of $\frac{100}{m + 2}$. It is not difficult, but a little more trouble, to make the calculations without tables.

For the benefit of photomicrographic members, the following is quoted from a note by Mr. Nelson. "This method will measure the foci of large photographic lenses. In that case $f = \frac{100}{m + 2} - \frac{100}{(m + 1)^3}$."

"This second term is only necessary when f is large compared with one hundred inches; for microscopic lenses it is not wanted. The whole can be determined from reciprocal tables without putting pencil to paper." The tables referred to are those of Barlow, published by Messrs. E. & F. N. Spon.

The screw-micrometer eye-piece is, perhaps, a drawback. Mr. Nelson says, "An ordinary screw-micrometer with a negative eye-piece is no good for lens measurements; the eye-piece must be of the Ramsden type, and it is very doubtful if any ordinary ruled glass micrometer eye-piece would be sufficiently accurate. A screw-micrometer is necessary for both the methods described in the paper."

It will be noticed that Mr. Nelson lays stress on what he has named the Optical Index; but perhaps it is less apparent that this paper on the magnifying power of objectives, and his communication to the last meeting on their aperture, are quite closely related to the Optical Index—in fact, they deal with both the values involved in the formula for the Optical Index of an objective $= \frac{\text{Numerical Aperture} \times 1{,}000}{\text{Magnifying Power}}$.

A general way of expressing the meaning of the Optical Index of an objective is that it is the ratio of its aperture to its power.—J. GRUNDY.]

SOME OBSERVATIONS CONCERNING SUB-STAGE ILLUMINATION.

By S. C. Akehurst, F.R.M.S.

(*Read January 27th*, 1914.)

Plates 20–22.

The accepted method, and the one generally used, for sub-stage illumination is that known as the solid cone of light, controlled, within certain limits, by the iris diaphragm. Another form—that is, annular light—is occasionally used, but is not considered by many microscopists to be of value for critical work.

Both these forms of illumination are too well known to need detailed explanation. The textbooks, however, have very little to say either for or against the latter method, excepting Cross and Cole, 3rd edition, where a definite statement in favour of annular light is to be found. I cannot do better than quote this: "Stops can be further used for strengthening the contrast in the image with large cones of illumination and objectives having high apertures. This method does not minimise in any way the effective working of the objective, for, with objectives of large aperture, rays may be present which only impart brightness to the field, but do not contribute to making visible the fine detail upon the object. If less than half of the lateral spectra are seen on looking down the tube at the back lens of the object glass with a striated object in focus, then the *central* portion of the direct beam or central disc has no lateral image corresponding to it in the portions of the spectra that are visible. Under these circumstances, that central portion of the central disc in no degree contributes in enabling the detail to be seen, but only produces a haze; by blocking it out the haze is removed and there is a great

improvement in the resulting definition." Mr. J. W. Gordon's opinion is that when a suitable stop is employed in the sub-stage condenser there is no objection to using annular light with an oil-immersion objective of high numerical aperture. It is, however, necessary that the outer zones of the objective used should be well corrected. His own method of blocking out the central beam is to use a stop over the eye-piece—and this is fully described in the *Journal R. M. S.*, February 1907. On the other hand, Carpenter does not entirely agree that annular light is permissible. Quoting from the seventh edition, he says, "If it is required to accentuate a known structure, *such as the perforated membrane of a diatom*, it can be done by annular illumination, which means the same arrangement as for dark-ground but with a stop insufficiently large to shut out all the light. This method is not to be recommended when a structure is unknown, as it is also liable to give false images."

Mr. Nelson has also expressed himself against annular light, stating that whilst strong resolution of diatoms is obtained by this method of illumination it also gives rise to spurious images.

The subject of sub-stage illumination is a large one, and I am only dealing with one phase of it, viz. annular light produced by a reflecting condenser, to be used in conjunction with an oil-immersion objective, for resolving the fine structure of diatoms and displaying stained bacteria.* When a wide-angle refracting condenser is employed, with stop to produce annular light, trouble arises through chromatic aberration, which is especially noticeable when an objective of high aperture is used. This dispersed colour is objectionable, as it operates against a pure image being formed, and is also detrimental to obtaining faithful records by photography. Much has been undertaken to demonstrate that, in practice, light from a condenser exhibiting chromatic aberration

* A slide of Tubercle bacilli was exhibited illuminated with annular light, showing that the reflecting condenser works well with small stained objects in addition to diatoms.

does not prevent good work being accomplished. On the other hand, I believe the reduction of chromatic dispersion to a minimum leads towards an ideal system for critical work.

The question now arises, if annular light is employed with objectives of high aperture, how is the trouble arising through chromatic aberration to be avoided. I suggest reflected, instead of refracted, light being used. I came to this conclusion after making a number of observations with a Leitz concentric reflecting condenser. This condenser has two reflecting surfaces, one convex and the other concave, and, as the rays are brought to a focus by reflection only, there is no chromatic dispersion, and spherical aberration is reduced to a minimum. The elimination of spherical aberration, however, is not a matter of importance. This was pointed out to me by Mr. J. W. Gordon, who has very generously allowed me to make use of his remarks on this point.

He says: "Light from the periphery of the condenser may exhibit defects due to spherical aberration. This light, on reaching the object, sets up a new impulse, and the rays emerging from the object, and travelling towards the eye, will, in any plane conjugate to the plane of the stage, appear free from the original defects of spherical aberration—just as if they had started from an independent source. No false images would, therefore, arise from this cause in the image plane when light is used from a sub-stage condenser that has not been corrected for spherical aberration." It should be carefully noted that this reflecting condenser was produced to obtain dark-ground effects, and was never intended to be used in the manner I have employed it—that is, in conjunction with a $\frac{1}{12}$ inch oil-immersion objective *without* a funnel stop to reduce the N.A. of the objective. In its present form the reflecting condenser I have passes too much light. The results obtained, however, were sufficiently striking to arrest attention when resolving fine structure of various diatoms. The transverse striae of *Amphipleura pellucida* in monobromide of naphthalin were displayed. In realgar the same details were strongly shown,

and when the mirror was slightly tilted, if the diatom was a suitable one, it was resolved into dots. A good image of the rosettes on *Coscinodiscus asteromphalus* was obtained, which stood a high-power eye-piece well. With the mirror slightly tilted, the faintly marked transverse striae were visible on *Cymatopleura solea*—also an excellent black-dot image was displayed of *Navicula rhomboides*, *Surirella gemma* and *Pleurosigma angulatum*. On examining a strewn slide of *Navicula rhomboides* in realgar I found a specimen of *Pinnularia nobilis*? On tilting the mirror and obtaining oblique light the costae were filled with dots. Particulars of this were forwarded to Mr. Nelson, who replied as follows: "Mr. Merlin and I have seen the structure on Pinnularia to which you refer. It was demonstrated upwards of twenty years ago by H. Gill, who filled up the apertures in diatoms with platinum—some of these specimens I have still." I am pleased to be able to give this report, as it helps to dispose of the idea that might arise that the dots displayed were probably due to false images, brought about by using annular light.

The opaque lines on an Abbe test plate were well defined, and an excellent rendering of stained bacteria, such as Tubercle bacilli, was obtained. In all the tests referred to the following combination was used: Incandescent gaslight, Nelson stand condenser, Leitz concentric reflecting condenser and fluorite, $\frac{1}{12}$th inch oil-immersion objective N.A. 1·35, Winkel complanat eye-piece, and Wratten B screen.

During the autumn of 1913 Mr. O'Donohoe became interested in this reflecting condenser, and he spent an evening with me examining some of the test objects referred to; and afterwards kindly undertook to see if any results worth attention could be obtained by photography when using this type of condenser. He was successful in getting a record of the dots on Pinnularia.*

I am very much indebted to Mr. O'Donohoe for the ready manner in which he undertook the work of testing the condenser,

* T. A. O'Donohoe: "An Attempt to Resolve *Pinnularia nobilis*," p. 309.

and for the photographs which illustrate this paper; and you will agree with me that without these records my remarks concerning the value of reflected annular illumination would have been much less convincing.

Summary of the Advantages in using Annular Light produced by Reflecting Condenser.

(1) When employing an achromatic condenser excess of light is reduced by closing the iris diaphragm. This involves a sacrifice of the numerical aperture, and, therefore, loss of resolution. With the reflecting concentric condenser there is no loss of high-angle rays, the excess of light being modified by stopping out a portion of the central or dioptric beam; the fullest possible advantage can, therefore, be taken of the numerical aperture of the whole optical system.

(2) Chromatic dispersion being entirely eliminated, a pure image is obtained.

(3) The absence of colour in the field admits of critical work being done by photo-micrography.

(4) When necessity arises to search a slide for minute striae, or other fine structure, it is immaterial in which direction across the field the striae appear—they are resolved.

(5) The simple construction of this type of condenser admits of it being produced at about half the cost of an achromatic oil-immersion condenser; and whilst it can only be employed with a $\frac{1}{12}$th inch oil-immersion objective in the manner already described, yet it gives excellent dark-ground effects with all powers from $\frac{1}{12}$th to $\frac{1}{6}$th inch.

One defect—if defect it can be called—is that, in its present form, there is no method of controlling the light passed by altering the size of the stop. It is just possible means can be devised to allow of this being done.

In my opinion there appears to be room for a reflecting con-

denser to be used with high-angled oil-immersion objectives, even though the field for its usefulness may be limited.

I hope the photographs illustrating this paper will prove of sufficient interest to stimulate further investigation into the value of annular light, and to demonstrate what limits, if any, should be put upon its use.

Descriptions of Plates.

Plate 20.

Figs. 1 to 7 are illustrations of various figures of the spectra of *Pleurosigma angulatum* as seen at the back lens of an oil-immersion objective with the diatom in focus—an achromatic condenser, with and without stop, and reflecting condenser being used. Figs. 1 to 3 are of no special interest just now—most of you are familiar with these diffraction spectra, varied according to the diameter of the opening in the iris diaphragm.

Fig. 1 shows result obtained with the diaphragm almost closed.

Fig. 2 the diaphragm is opened so that one-third of the back lens is in shadow. The details of the diatom are hardly perceptible, being flooded out by excess of light.

Fig. 3. The iris is closed, until two-thirds of back lens is in shadow. In this position, with the spectra just touching the edge of the central beam of light, the best resolution of *Pleurosigma angulatum* is obtained.

Fig. 4 shows the spectra obtained when a large spot is used. The six diffraction spectra forming the symmetrical image should, however, be slightly moved from the centre outwards to reduce the diameter of the hexagonal spot in the centre, which in the drawing is a little too large. In this instance insufficient light was passed, and an unsatisfactory image of the diatom was displayed. My next spot being too small, the picture of the spectra obtained is as shown by fig. 5. Here we have six dark cuspidate forms, disposed as a six-pointed star, the intermediate spaces being filled with a diffused light, the whole figure being some-

what ill-defined. This effect was due to an excess of light; by slightly closing the iris diaphragm the light was reduced, and we have the result as shown in fig. 6—the symmetrical design well defined on a black ground, and just a glimpse of another portion of the spectra at six points round the shadow caused by the partly closed diaphragm. With the spectra showing, as illustrated in fig. 6, I obtained the best definition of *Pleurosigma angulatum* with achromatic condenser and spot.

Fig. 7 is the record of the spectra obtained of the same diatom, using the reflecting condenser; the similarity between the figures 7 and 5 is noticeable.

My reflecting condenser—to work at its best when using it for annular light—requires the light cut down until a crisp image is shown of the spectra as at fig. 6.

Fig. 8 represents the rulings on an Abbe test plate, as displayed by $\frac{1}{12}$ inch oil-immersion objective and reflecting condenser. The position of the light bars is to be noted; there are six—those at the top and bottom are not quite fully displayed. On first examining the back of the objective I observed the two rows of six white dots, as shown at fig. 9. At another examination—the light probably being more central—I found an almost complete circle, as at fig. 10, made up of ten white dots on each side and a thin streak of light at the bottom. I have not yet been able to put forward a suggestion as to how these are formed. I have, however, included them in my record, as they may be of some interest.

Plate 21.

Fig. 1. *Nitzschia linearis* × 2,500, showing the white-dot image. This photograph was taken with a highly corrected oil-immersion condenser and axial illumination.

Fig. 2. *Nitzschia linearis* × 3,000, this time showing the black-dot image. This photograph was taken with reflecting concentric condenser.

Both these pictures were taken by the same man, using the same objective, diatom and illumination—the only difference being in the condenser used. Regarding this matter, Mr. O'Donohoe writes as follows: "I was never able to see the black-dot image when using my ordinary oil-immersion condenser, hence was much surprised to find that the reflecting concentric condenser showed the black dots beautifully. This and the Amphipleura show that the reflecting condenser is a better resolver than my ordinary oil-immersion condenser and axial illumination.

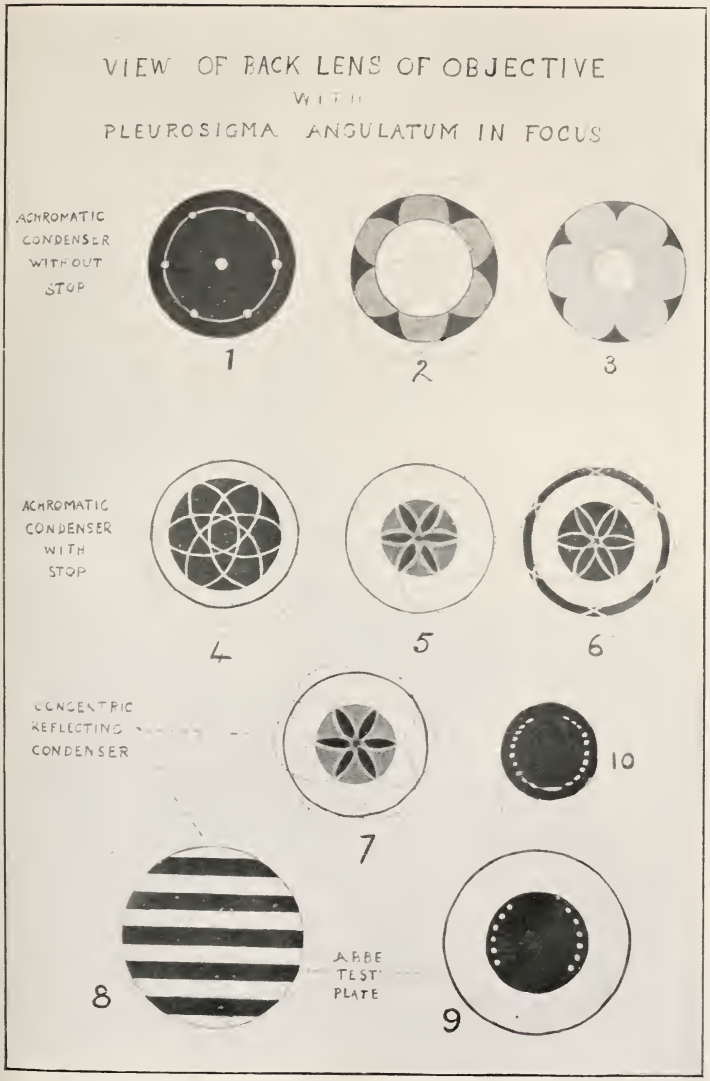
Fig. 3. *Amphipleura pellucida* × 2,000. This photograph was taken to demonstrate the usefulness of annular light when searching a slide for fine structure. The diatoms are at right angles to each other, and both resolved. Had light in one azimuth been employed, such as one gets with an achromatic condenser, and quarter-moon stop, only one would have been resolved, viz. the diatom with striae at right angles to the direction of the beam of light.

Fig. 4. A record of *Surirella gemma* × 2,000. This was taken with the reflecting condenser. The black dot is shown, and at the same time the ribs are resolved into dots.

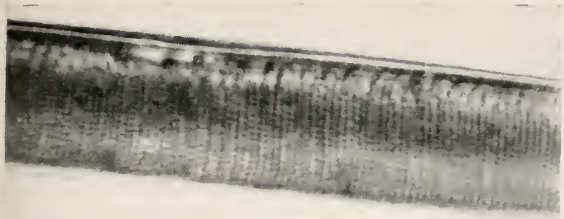
Plate 22.

Fig. 1. *Navicula rhomboides* × 1,500, taken with the reflecting condenser.

Fig. 2. *Pinnularia nobilis* × 2,500, showing the costae filled with dots. Taken with the reflecting condenser.



C. H. Caffyn, *photogr.*



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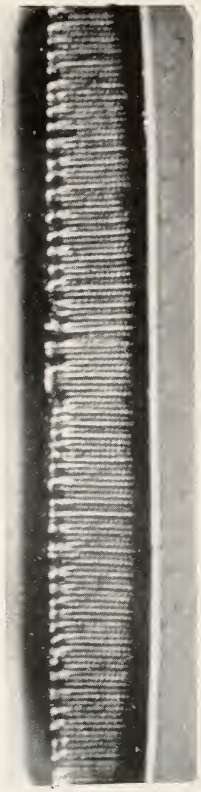

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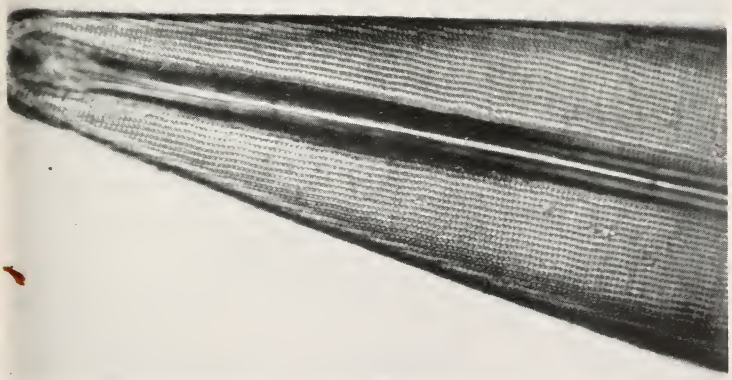
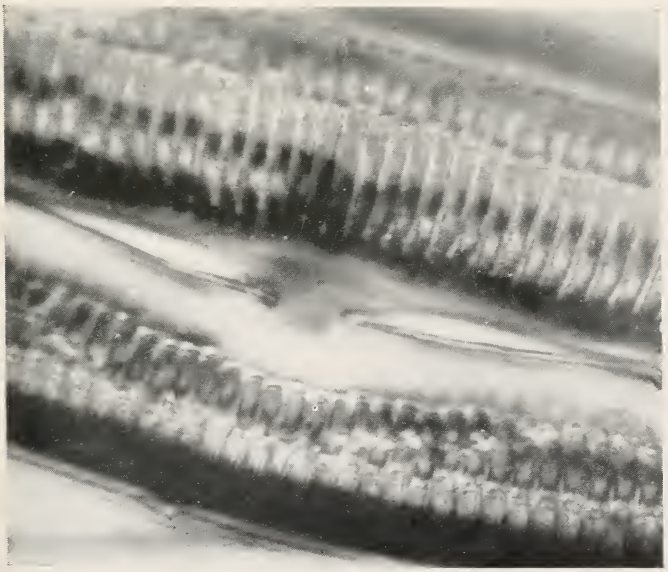


4

T. A. O'Donohoe, *photogr.*

Resolution with Annular Illumination.

1



2

T. A. O'Donohoe, *photogr.*

Resolution with Annular Illumination.

AN ATTEMPT TO RESOLVE AND PHOTOGRAPH *PINNULARIA NOBILIS*.

By T. A. O'Donohoe.

(*Read January 27th*, 1914.)

Most microscopists are acquainted with the little diatom called *Pinnularia nobilis*, which, on the test slides of twenty diatoms mounted by Möller and Thum, takes the second lowest place, with striae numbering from 11,000 to 12,000 to the inch. It is just because it occupies such a lowly place that it is passed over with contempt as being worthy of the notice only of the babes and sucklings of microscopy who find themselves in possession of a 2-inch or 1-inch objective.

Such was my own feeling towards it until quite recently, when Mr. Akehurst showed me by resolution into dots that it deserved a better fate, and invited me to resolve and photograph it, if I could, and for this purpose he, at the same time, lent me a realgar mount and the reflecting dark-ground condenser of Leitz. I have since learnt that an objective and illumination which, without any manipulation, showed me at once the striae of *Nitzschia linearis*, *Frustulia saxonica*, and *Amphipleura pellucida*, and the very distinct black dots of all the other diatoms on Thum's test plate of 30 forms, failed completely in inducing the *Pinnularia nobilis* on the same slide to yield up its secrets. So that the diatom to which almost the lowest place is assigned by the mounter is, in fact, by far the most difficult to resolve. Examined with a dry lens of N.A. 0·85 and direct cone of light, we get an image in which on each side of the raphe are seen two zig-zag lines running from end to end and dividing the finger-like bands into three series—or each band into three compartments. This is all that can be seen with a dry lens.

Now using a Zeiss 2-mm. apochromat N.A. 1·3, and Watson's Holoscopic immersion condenser, and finding a central cone of light unavailing, I inserted the crescent stop in the condenser, and proceeding as if I were resolving the striae of *Amphipleura pellucida*, I succeeded in getting an image which shows what one

must call the costae, broken up into three parts, with very fine lines between them. It may be seen that the middle parts of the costae are in the sharpest focus because they represent the highest of three distinct planes. Now if this interpretation be correct, the structure of this diatom is very complex, as there would be three planes on each side of the raphe, and the planes on the one side would coincide with those on the other only when the diatom was perfectly flat on the cover-glass—a very unlikely case.

I now tried to resolve the costae, with the result as shown [here an image was projected on the screen], which reminds one of the bones of a skeleton's hand.

There remained the resolution of the very fine lines between the costae, probably into dots. After trying to do this many hours without any success I substituted Mr. Akehurst's dark-ground condenser for the Holoscopic, with the result that, after considerable manipulation I was able to get the photograph here reproduced. (See Pl. 22, fig. 2.) This shows at least partial resolution on both sides of the raphe.

NOTES.

ON A METHOD OF MARKING A GIVEN OBJECT FOR FUTURE REFERENCE ON A MOUNTED SLIDE.

By James Burton.

(*Read November 25th*, 1913.)

Most likely all of us at times have come across some particular object on a mounted slide which we have felt we should like to be able to find on another occasion; perhaps some special diatom on a strewn slide, for instance. Now there are several methods of doing this, and a little piece of apparatus is sold by the opticians which marks a circle round an object first found under the microscope. But perhaps with the majority the necessity does not occur often enough for it to be worth while to keep a special tool, and the little dodge, if I may call it so, which is here described can be carried out without any other instrument than those we most of us already have and use. If the object to be marked is sufficiently large for recognition under a moderate power, such as can be obtained with a hand lens or dissecting microscope, the matter is very simple. First find the object, then with a fine camel-hair or sable brush carefully place a dot of water-colour over it large enough to be seen with the naked eye, set it on one side to dry; when dry, put the slide on the turn-table with the dot accurately in the centre and turn a small ring round it with any dark cement you may have in use; when this is hard, which will depend on the kind of cement used, the water-colour can be removed with a damp brush, and the cover can be carefully cleaned with a piece of soft rag.

If the object, however, is too small to be readily recognised without a high power, as, of course, is usually the case, for it is not necessary to mark anything but minute objects, a rather more complicated variety of the same plan should be adopted. Again first find the object with a suitable power, such as a $\frac{1}{4}$ inch or $\frac{1}{6}$th inch, and let the specimen be as

accurately placed in the centre of the field as possible; then substitute for this power, preferably a water-immersion objective, say $\frac{1}{10}$th, put on the front lens a small drop of water and carefully focus. It is necessary that the slide should not be moved after contact is made, as it is desirable to keep the drop of water as small as possible. When the object is recognised and is in the centre of the field, raise the microscope tube rather sharply and a small circular spot of water will be left on the cover-glass right over the desired place. Now stain this spot with water-colour as in the other case—I always use the carmine kept for feeding infusoria, etc., but any colour will do. When this is dry the slide may be roughly examined and the object will be seen through the coat of colour, which for this purpose should not be too thick. If it be rightly placed, proceed as before, putting a fine ring of suitable size round the spot with some dark cement, and when this is dry carefully clean off the colour, and the arrangement is complete. Water-immersion lenses are not very commonly used now, and if the microscopist does not happen to possess one, an oil-immersion may be used instead, but obviously it must be used with water, not oil; but this will give a sufficiently good image for our purpose, which is merely to recognise the specimen for marking, not to examine it. If an oil-immersion be not available, any close-working objective, say $\frac{1}{8}$th inch or even $\frac{1}{6}$th inch may be used, but it is necessary that the front lens be a small one, so that the spot of water placed by it should be as local as possible.

There are, of course, some difficulties; the chief is, that objects mounted in glycerine—as mine usually are—are somewhat liable to move if at all roughly handled, and may work out of the circle; but with balsam or glycerine jelly mounts, or even a shallow glycerine one, there is little danger of this. If a turn-table is not in the outfit of the experimenter, a sufficiently good circle may be drawn by hand, or a line drawn to indicate the position, or, as has been suggested, the barrel of a mapping pen or similar object may be used. But the first great difficulty is always to indicate the exact spot it is desired to mark, particularly if the object is a very minute one, and that is got over with facility by the method indicated.

A LIVE BOX FOR THE OBSERVATION OF INSECTS AND SIMILAR OBJECTS.

By B. M. Draper.

(*Read December 23rd*, 1913.)

This live box, which was worked out for me by Mr. Angus, displays satisfactorily, with superstage illumination, under the lowest powers, large creatures such as house-flies. It is not meant for pond-life.

It is of the simplest description, being really nothing but a transparent chamber of the shape and size of a small pill-box. The body is made of a short piece of glass tube of any size desired, say, one-third of an inch deep by two-thirds in diameter; this is cemented to a 3 × 1-inch slip. The lid, which is loose, is a circular plate of glass of rather larger diameter than the body. In the lid, near its circumference, and at equal distances from each other, are fixed three short pins, projecting downwards, so as to clasp the outside of the body and thus keep the lid in position. The little collars by which the pins are fixed in the lid rest on the rim of the box, so as to prevent the lid itself from touching. The crack thus left gives enough ventilation. The depth of the box can be varied by means of a false bottom, preferably opaque.

This box serves well for the exhibition of a fly in the act of feeding. If a little syrup is put on the inside of the lid of the box, the sucking surface of the proboscis may be seen in action.

DARK-GROUND ILLUMINATION WITH THE GREENHOUGH BINOCULAR.

By B. M. Draper.

(*Read December 23rd*, 1913.)

The Greenhough pattern of binocular consists, as is well known, of two separate microscopes, one for each eye, with paired objectives of very low power. Like other binoculars, it is particularly well suited for use with dark-ground illumination, and a good way of getting the dark ground with its higher powers is to put a stop behind the condenser.

As, however, the front lenses of the twin objectives stand out some distance on either side of what would be the optic axis of an ordinary microscope, the stop has to be correspondingly broad from side to side; otherwise direct rays would enter the objectives and would spoil the dark ground at the sides of the field. But it is not necessary that the rectangular diameters of the stop should be equally great; on the contrary, if an ordinary circular stop be used, some rays are needlessly obstructed. On trial, a double or twin stop, corresponding with the twin objectives, gave much better results. This stop consists of two small circular patches placed side by side in the same plane, and touching each other, so as to form a figure of eight. It is used behind the condenser in the same way as an ordinary circular stop, and with almost equal ease. It is only necessary to be careful that the two circular patches shall be placed horizontally, *i.e.* so as to be opposite the two front lenses of the twin objectives. This position can easily be secured by arranging the stop in the carrier approximately and then, whilst watching the object, shifting the whole condenser round in its sleeve until the best effect is obtained. A standard low-power condenser such as Swift's "Paragon," with its top lens off, gives very satisfactory results. The twin and the ordinary circular patterns of stop were compared experimentally by using a condenser fitted with two stop carriers, one behind the other, so that either stop could be used separately, or both together. The twin stop used by itself gave a good dark ground. The circular stop was purposely chosen too small to give a good dark ground; there was light at the sides of the field. Nevertheless when the circular stop was turned in above the twin stop whilst the object was under observation, there was a marked drop in the brightness of the image. This loss of light was due almost entirely to the circular stop, not to the clear white glass on which it was mounted, since it was found that the interposition of such a piece of glass, even when rather dirty, made very little difference to the light. Evidently, therefore, the circular stop, though too small in one direction, was too large in the other, and kept out some rays which might safely have been admitted. Of course if the circular stop had been large enough to darken the background when used by itself, the loss of light would have been still more noticeable.

AMPHIPLEURA LINDHEIMERI.

By Edward M. Nelson, F.R.M.S.

(*Read December 23rd*, 1913.)

Half a century ago *Navicula rhomboides* was the accredited test for the best microscope lenses. This was the common "English" *rhomboides*, which has about 72,000 to 73,000 striae per inch; it was also known as the Amician test. About the seventies *N. rhomboides* was discovered in America. This was a coarser form, having some 60,000 striae per inch, consequently any 90° $\frac{1}{4}$ inch N.A. 0·71 would resolve it readily. In those days there were no cheap apertometers to be had, so testing an objective merely meant a measurement of aperture by resolving striae on some diatom by means of oblique light in one azimuth. We now know that the feat can be accomplished by a very badly corrected objective.

The new coarse American *rhomboides* became very popular, and diatom dotters and brassey glassites simply revelled in it.

History has, however, repeated itself, for as time went on lenses improved, and both the coarse and fine *rhomboides* failed as tests for high powers, so others had to be found to fill their place. *Amphipleura pellucida* became the test for immersions, while *A. Lindheimeri* was used for dry lenses. As *A. Lindheimeri* has about 7[illegible],000 striae per inch, it is a very suitable test, with oblique light from a dry condenser, for lenses of the 7A type.

This was the favourite test of the late Lewis Wright, who mentions it in his excellent book on the Microscope. But now another *Lindheimeri* has been discovered in Spain, and as it is a coarser variety, it is necessary to distinguish between these forms when quoting the *Lindheimeri* as a test. The new *Lindheimeri* has 67,000 striae per inch, and therefore is easier to resolve than the old English *rhomboides*; a $\frac{1}{2}$ inch, or 8 mm., will very nearly resolve it—in fact, they do so in patches; a Powell 100° $\frac{1}{4}$ inch of 1875, which would fail on an English *rhomboides*, resolves it easily.

The new *Lindheimeri* can be recognised at once by its very long terminal nodules, the terminal nodule being one-third of the whole length of the valve, while in the old form it is only one-fifth.

The length-breadth ratio in the new form is 7·5, and in the old 8·5.

The conditions here are therefore opposite to those we found in *Navicula rhomboides*,* for those with the greater ratio had the coarser striae, but in this case they have the finer.

If we divide the ratio by the number of striae in $\frac{1}{10000}$th of an inch we shall obtain a numerical index of about 1·1. Thus:

Old *Lindheimeri*: Ratio 8·5, striae 7·7, index 1·1.

New *Lindheimeri*: Ratio 7·5, striae 6·7, index 1·12.

Amphipleura pellucida follows much the same rule, for "resolvers" who understood the subject sought out wide valves, *i.e.* those with a small ratio.

* *Journal Q.M.C.*, vol. xi. p. 97, 1910.

SOME NOTES ON THE STRUCTURE OF DIATOMS.

By N. E. Brown, A.L.S.

(*Read March 24th*, 1914.)

Plate 23.

These notes are offered to the Quekett Microscopical Club, not with the anticipation that, with the exception of one point, the expert will find in them much that is not already known, but because my interpretation of certain familiar features is different from that which is usually accepted and may therefore be of some interest in promoting thought in another direction.

Structure of Pinnularia spp.—Although *P. major* and allied species are familiar to all microscopists and their structure is doubtless well understood by experts, yet the description of it in English text-books is by no means satisfactory and also does not seem to be too well known. A good description with figures by Floegel will, however, be found in the *Journal of the Royal Microscopical Society*, 1884, vol. 4, p. 509, t. 8 (*Pinnularia*).

I regard *P. major* as a very simple type, perhaps one of the simplest types of diatom-structure. In front view the valve presents a series of transverse markings on each side of the raphe, which are so easily seen that I believe few diatom-dotters pay much attention to them. These markings consist of linear cavities or canals in the valve, separated from one another by very thin partitions, and each of them is provided with a comparatively large linear-oblong opening on the inner side, communicating with the interior of the diatom; it is evident that during life the protoplasm enters and fills these cavities, and therefore they must play an important part in the life-economy of the diatom. The motions of a living diatom are not only interesting to watch, but are puzzling to every one who has observed them. It is no uncommon thing to see a *Pinnularia* or other free-swimming diatom apparently take hold of a particle of dirt and move it to and fro along its sides or upper surface. On one occasion I saw *P. major* with two fragments of dirt, one on each side of it near the margin; both pieces were moved forwards and backwards in the same direction for a time and then suddenly they were moved each in a different

direction, and finally one piece was passed from one side completely round one end to the other side, where, upon meeting the other piece of dirt which was moved towards it, the invisible hands moving the dirt lifted it up and placed it upon the other piece of dirt and held it there, both together being then moved up and down as before. Now this and other movements I have witnessed could only have been made at the will of the diatom, and in my opinion must have been controlled by living matter extruded from the interior of the shell, and therefore there must be openings through which the interior is in communication with the exterior other than at the raphe, where, as is well known, a crest of protoplasm extrudes, which, from measurements I have made, varies from 1/14,000th to 1/3,000th inch in depth and 1/6,000th to 1/1,800th inch in breadth. Feeling convinced of this, I sought for several years for evidence of pores in *Pinnularia* without finding the slightest trace of them, and all authors I have consulted state that there are no openings in the valve of *Pinnularia* other than at the raphe. With respect to diatoms in general, in the 8th edition of *The Microscope and its Revelations* (1901), p. 590, it is stated, "We have in fact no positive demonstration of the existence of special apertures communicating between the outside and inside of the cell."

However, some four years ago I obtained a sample of the Cherryfield diatomaceous deposit, and upon mounting some of it in picric piperine, found that it contained four or five species of *Pinnularia*, on one of which I at last saw indications of the pores I had so long sought. This species is one of the smallest in the material and the only one on which I have been able to see any indication of pores. They are only to be seen when the outer surface of the cavities is accurately in focus and the light central, and are so minute and crowded that they appear like a single dusky beaded line extending all the way along the centre of the cavity, and they do not appear to be present at any other part. At any focal plane below the external surface, such as when the large opening into the interior of the diatom is in view, they cannot be seen. When viewed from the inside of the valve they are scarcely visible except where seen through the large opening of the cavity into the interior. Although a distinct bead-like appearance is just discernible, the pores are so closely placed that neither I nor the friends to whom I have shown them, have been able to see them

as distinctly separate dots. It is only on this particular species, the name of which I do not know, that I have been able to discern these pores. Upon the far larger *P. major* and *P. nobilis* I cannot see any trace of them, although I do not doubt that they exist in these species also, but are probably smaller than in the species in which I discovered them. As seen by myself and friends at a magnification of 3,000 diameters they are as represented at Pl. 23, fig. 13.

Upon the sides or girdle of all species of *Pinnularia* are to be seen two slender lines, which under sufficient magnification are seen to be composed of a multitude of short transverse lines; in *P. major* these average about 60,000 to the inch. These lines I have failed to resolve into distinct dots, although Mr. E. M. Nelson (*Journ. Q. M. C.*, Ser. 2, Vol. VI. p. 144) states that he has done so, and I do not doubt his statement. But at the same time I very much doubt if the dots of which these transverse lines are composed are real pores. The lines are so easily seen that they evidently are much too coarse for pore structure, and my interpretation of the structure of these two lines on the girdle of *Pinnularia* is, that each line consists of a multitude of very minute cavities placed side by side, similar to those seen in the front view of the valve, and that when they are truly resolved each cavity will be found to have a minute pore at the centre or a row of pores along the central line of each cavity or clear space between every pair of short transverse lines.

It may be well to state that there are sometimes appearances to be seen on the walls of the cavities of *P. major* and *P. nobilis* which may easily be mistaken for rows of pores. As I have seen them, they appear like two rows along each cavity, but upon moving the mirror slightly these rows move also, and clearly demonstrate that they are only diffraction images. The true pores of these species, when discovered, will, I believe, be in one central row.

Pleurosigma balticum.—In a paper recently published in the *Journ. Q. M. C.*, Ser. 2, Vol. XII. p. 155, Mr. T. O'Donohoe has given an account, accompanied by some excellent photographs, of certain details of structure of this diatom as seen in a strewn slide mounted in realgar belonging to Mr. B. J. Capell. By the courtesy and kindness of Mr. Capell I have also had the privilege of examining this slide, and am fortunate enough to be able to

add something concerning the structure to be seen on it that appears to have escaped the eyes of Mr. O'Donohoe.

In the process of melting the realgar, either the great heat required, or some chemical action set up by it, has acted upon some specimens of *P. balticum* and completely dissolved part of the shell, leaving only film-like strips flattened upon the cover-glass, whilst others have been quite unaffected. One specimen shows in a very clear manner the dissolving action in progress, but arrested at the moment when a subcentral part of the diatom had become fused into a structureless strand of silica, connecting the two ends, which remain intact. These films above mentioned, which Mr. O'Donohoe has photographed, will prove, I think, to have an important bearing upon our more complete understanding of diatom structure.

If the outer surface of a perfect valve of *P. balticum* be examined under a binocular, it will be seen that the sides curve away from the raphe very much as the sides curve away from the keel of a boat when turned bottom upwards, so that the surface is nearly always oblique to the surface of the cover-glass. From this cause I have found the structure of a perfect specimen extremely difficult to understand, as a very slight modification of the illumination or alteration of focus under high powers, or the two combined, produce a number of different appearances—six or seven have been noticed—all apparently demonstrating true structure, so that it is practically impossible to form an opinion as to which view, or views, represent the real structure of the valve. Owing to this, I suppose, has arisen the diverse views held of the structure by different authors. O. Müller, for instance, in the *Deutschen Botanischen Gesellschaft* for 1898, Vol. XVI. p. 387, t. 26, fig. 8, regards the pores (by which I understand he means the black dots) in the cell-wall as perforations passing completely through the wall, which are not perfectly tubular, but enlarged at their centre and contracted to a minute opening on the internal and external surface of the valve thus :

Mr. T. F. Smith, however, in the *Journ. Q. M. C.*, Ser. 2,

Vol. III. p. 306, regards the valve as "composed of two layers of grating"; whilst Mr. E. M. Nelson in the *Journ. Q. M. C.*, Ser. 2, Vol. XII. p. 99, fig. 4, states that "in *P. balticum* and allied forms the upper membrane has slit-like apertures in longitudinal rows, while the lower membrane has circular apertures (fig. 4), where the circular apertures in the lower membrane are seen through the intercostal silex of the upper membrane and in a line between the slits." Finally we have Mr. O'Donohoe's interpretation referred to above.

Until August 1913 I held the view (which I think is the prevailing one) that the black dots visible on the valve of a diatom were pores or perforations passing completely through its substance, and that the white-dot view was an out-of-focus one. Now, however, the examination of Mr. Capell's slide has demonstrated to me and to others who have examined it with me, conclusively and beyond any room for doubt, that many (possibly all) of the black dots that are ordinarily seen on a diatom are not pores at all, or at the most are only pits containing the pore-bearing membrane, and that the white-dot view is often much more correct for seeing what I believe to be the true pore-structure than has been supposed.

I have long been puzzled at the behaviour of black dots under high magnification, and have therefore suspected that they were not quite what they seemed to be for some time past, but I think the evidence of Mr. Capell's slide fully explains their nature.

In any perfect valve of *P. balticum* it is easy to obtain a view of a grating-like structure with square meshes, formed of bars or rods of silex crossing one another at right angles. In the partly dissolved films on Mr. Capell's slide this grating is not evident, but instead the films are seen to consist of parallel dark rods having a beaded appearance, held in place by a membrane of silex (see Mr. O'Donohoe's figures, *op. cit.*, t. 14, figs. 3 and 4). At the ends or other parts the rods are seen to project in a ragged manner. These rods are those which lie parallel to the raphe in the perfect grating, while those which in the perfect diatom form the transverse bars of the grating structure have been dissolved, leaving no trace, or only a very faint one, visible. When examined with an oil-immersion objective at a magnification of 2,000 to 3,000 diameters these bars are

seen to be thickened in a beaded manner at short equal intervals. In some cases a few of these rods are curved away from the surface of the valve, and one of them in such manner that part is seen in surface view and part seen in side view, and traceable from one view to the other (see Mr. O'Donohoe's photograph, *op. cit.*, t. 14, fig. 2, where it or a similar rod is shown out of focus). Now it is obvious that the bead-like swellings occur at the points where, in the perfect grating, the transverse bars crossed and were fused with those parallel to the raphe, and that these transverse bars were either more easily dissolved or lie at a slightly lower level than the longitudinal bars, and so are more quickly attacked by the dissolving action. In all cases the films are very closely applied to the cover-glass, indicating that its cooler surface has in some way retarded the dissolving process, so that the parts of the diatom farthest from the cover-glass were always dissolved first. That the longitudinal bars overlie the transverse bars seems to be probably the correct view, as under certain conditions of illumination the longitudinal bars seem to pass over the transverse ones, and is supported by the testimony of the curved bar mentioned above as seen in side view. At a magnification of 3,000 diameters it is clearly seen that the edge of the bar facing the outside of the diatom is perfectly even, while the edge facing the interior projects into little hemispheres at the points where (in surface view) it is bead-like (fig. 2). Also at the marginal part of the valve, where the longitudinal bars are normally undeveloped and only the transverse bars are evident, these latter become pressed nearer to the cover-glass, and are not dissolved.

The bars can be distinctly seen to be solid pieces of silex, which go to form the strengthening grating and support the membrane which covers the exterior of the diatom. At a certain focus the beads or nodes at the crossing of the bars, owing to refraction or diffraction, assume the appearance of black dots so familiar to all microscopists, demonstrating conclusively that these black dots are not pores, but shadows produced by some refractive or diffractive property of the nodes of the grating-bars.

From the movements I have seen diatoms perform it is evident they must have some means of communication through the valves with their surroundings, and finding that the black dots on this diatom are certainly not pores, I sought for them in the membrane

covering the meshes of the grating. This membrane is extremely thin, probably not thicker than the film of a soap-bubble, and is raised into a slight dome or convexity over each mesh of the grating. When the apex of these convexities is accurately in focus, and the beadings of the bars seen as black dots forming squares, the light being central and with a magnification of 2,000 to 3,000 diameters, a very minute dot is seen at the centre of each square (Pl. 2, fig. 1). This central spot I conceive to be a true pore through the membrane; it is very minute, at the most not more than one-third of the diameter of the black dots themselves, and is probably not more than 1/200,000th of an inch in diameter. It is not quite easy to see, but can be made clearer by the use of a small central stop in the substage condenser. I doubt if it can be seen at all at a less magnification than 1,000 diameters; and with a dry Zeiss $\frac{1}{15}$th, at a magnification of 3,000 diameters, I do not feel quite sure that I see the pores. There seems a suggestion of their presence, but I do not think any dry lens will show them very clearly. Under dark-ground illumination, with a Leitz dark-ground illuminator, the bars are white and the beadings on them appear much larger than when seen by direct light, whilst the membrane is not seen at all, the spaces between the bars being black. But if the funnel-stop which cuts down the aperture of the lens is removed, the illumination remaining as before, then the bars appear to be very slender and black and the membrane whitish, with the minute pores clear and distinct.

Upon entire specimens of the diatom the pores are difficult to see, apparently owing to the convex curvature of the shell, but with a little trouble I have been able to see them in places upon every specimen examined. Under certain conditions of illumination a small dark spot, which might easily be mistaken for the pore, is seen at the centre of each of the beads of the membrane; this spot, however, is very much larger than the true pore, and appears to be some diffraction image, possibly that of the stop in the condenser, as can easily be demonstrated by moving the mirror slightly, when the spot is seen to shift its position.

Although all to whom I have shown these pores agree with me that they are very minute, yet they appear to have a different size to different observers. To my eye they appear to have about the proportion to the black dots I have represented in my drawing,

to others they evidently seem larger, as one friend said he thought that about five of them just touching one another would extend right across one of the meshes of *P. balticum*, but even at that rate they would not be more than 1/180,000th of an inch in diameter, whilst I think they cannot be more than 1/200,000th of an inch in size.

With regard to Mr. Smith's statement that there is a second grating, I have not the slightest doubt that the transverse bars form such a grating, but I have not seen it separately from the outer grating. In *Knowledge* for 1911, p. 334, Mr. Smith reproduces a photograph of *P. balticum* in which the longitudinal strengthening bars are shown and are there called "fibrils," a term which Mr. O'Donohoe has also adopted, but which to me seems wholly inapplicable, as they appear to me to be supporting structures for the delicate membrane and in no sense ultimate structures. It may not be out of place here to point out that the membrane I speak of and illustrate is a totally different thing from that which Mr. Smith in the *Journ. Q. M. C.*, Ser. 2, vol. 3, p. 301, t. 3, fig. 5, and in *Knowledge* (1911), pp. 289-93, and 221-35, and (1912) p. 371 describes and figures as a "delicate membrane" and "torn structure." For it is a matter of great surprise to me that Mr. Smith did not recognise that this supposed "delicate membrane" and "torn structure" has no morphological connection with the diatom. I had supposed, previous to reading his paper, that every one regarded this appearance merely as an incrustation cementing the diatom to the cover-glass; it is of very common occurrence upon *Pleurosigma* and some other diatoms. I have always regarded it as due to the exudation of a residual salt, which, after boiling in acid, has not been thoroughly washed out of the diatom (and it is indeed very difficult to wash out completely), so that when mounting them on a cover-glass the water outside the diatom evaporates first and the salt then gradually percolates out through the pores of the diatom, and, in drying, fixes it to the cover-glass, and being of low refractive index produces the appearance we so often see.

It will be noted that there is a discrepancy between my drawings and Mr. O'Donohoe's photographs in the size of the black dots, for although mine are represented at a greater magnification, they are smaller than in the photograph. This is

probably because the photographs were taken at a focus where the membrane is not visible and where diffraction effects are at a maximum, whilst at the focus of the surface of the membrane they are reduced to a minimum.

Since writing the above I have had the advantage of being able to examine a realgar mount of *P. balticum* belonging to Mr. E. M. Nelson. The realgar of this slide is not nearly so clear and brilliant as that of Mr. Capell's slide, and on some parts of it I cannot see the pores in the films at all, but there are some films where they can be most distinctly seen. I mention this, because others possessing realgar mounts of this diatom might fail to find the pores on some of the films and believe them not to be present; they may be extremely difficult to make out, or quite invisible on parts of the valve where both longitudinal and transverse grating or strengthening bars are present.

Pleurosigma angulatum.—Upon Mr. Capell's realgar slide are also numerous specimens of this diatom; some are bent or contorted, but otherwise, with the exception of two or three specimens, seem unaffected by the heat or dissolving action. One of these exceptions, however, is an exceedingly interesting specimen, and clearly confirms Mr. E. M. Nelson's statement in the *Journ. Q. M. C.*, Ser. 2, Vol. XII. pp. 98-100, that the valve of this diatom is composed of two gratings. It is a single valve and therefore its structure is not obscured by images from the opposing valve, is fractured in places, and has its outer surface next the cover-glass, as can be verified by examination under a binocular. Over a small area some solvent has caused a portion of the outer grating to peel off, and at one place a small patch of it is seen adhering to the cover-glass; this patch is represented at fig. 5, as seen when magnified 3,000 diameters. At this magnification the bars of silex forming the boundaries of the meshes are seen to cross one another diagonally, forming diamond-shaped meshes, and are thickened at the nodes or points of intersection just as in *P. balticum*, and, as in that diatom, it is these nodes which produce the black-dot appearance. At the centre of the membrane covering each mesh a very minute pore can be seen when the surface of the membrane is accurately in focus. These pores do not seem to be visible under direct central light without the interposition of a stop in the condenser, and I find that they are best seen when illuminated by means of a Leitz

dark-ground illuminator, but without using a funnel-stop in the lens. Under this method of illumination they are remarkably clear and distinct, and the membrane itself appears to be slightly concave as viewed from the outside of the valve. At one focus and under slightly oblique illumination, one set of bars appears to cross over the other set, as I have represented diagrammatically at fig. 6 ; at this focus the pores are invisible. Upon the specimen from which the fragment is separated both the outer and inner gratings are seen to be composed of hexagonal meshes, as at figs. 7 and 8, and I find it very difficult to get a view of the diamond-shaped meshes on the entire part of this particular specimen, although upon other specimens I have been able to see them and the pores very clearly and easily, as well as the underlying hexagonal meshes. It would seem as if the outer grating may really be a double structure, with a film of diamond-shaped meshes overlying others that are hexagonal.

Under certain conditions of illumination a third set of bars can be seen on entire specimens, crossing the diagonals at right angles to the raphe, but I have failed to see any trace of them on the separated fragment represented at fig. 5, so that I think it very probable that they have been dissolved away from that piece, just as also appears to have been the case in the films of *P. balticum*. For I think there can be no doubt that some such bars exist, because at one focus, under varying conditions of illumination, the gratings appear to be composed of nearly square meshes as represented at fig. 9. At a very slight alteration of focus this appearance alters to the hexagonal one as represented at figs. 7 and 8, which I take to be that of the exact focal plane of the membrane covering the meshes of that particular grating. When the inner grating is examined where the outer grating is stripped off, looking upon it from the outside of the valve, it first presents the appearance of a solid plate of white silex with dark hexagonal perforations in it. At a slightly lower focus this gives place to hexagonal meshes with dark boundaries and the mesh covered with a clear membrane having a pore at its centre ; this latter I look upon as being the true image of the inner grating and the above-mentioned appearance of a white plate with dark perforations as an out-of-focus image produced by some refractive or diffractive property of the membrane, which in some way produces over each mesh a hexagonal shadow. Below the focus

of the hexagonal meshes I can sometimes make out a diamond-shaped arrangement of dark dots as seen in fig. 5.*

In this species, as in *P. balticum*, wherever a junction of two or more bars of a grating occurs, there a black dot is seen, due to diffraction or refraction of the node so formed. And in my opinion wherever grating structure occurs, the nodes may be expected to appear as black dots.

At one place a fragment of the valve is broken off and turned edgeways to the cover-glass. This edge-view shows the two gratings distinctly, but at the same time, owing to the shadow of the mass, I am quite unable to see how they are connected to each other. But from an examination of this piece, as well as of the valve where the outer grating is stripped off, it is evident that the faint brown colour peculiar to this diatom resides in the outer grating, the inner one being colourless.

I cannot, however, confirm Mr. Nelson's statement (*Journ. Q. M. C.*, Ser. 2, Vol. XII. p. 99) that the meshes of the outer and inner grating alternate with one another, for in this particular specimen I think there can be no question that the meshes of the outer grating are exactly superposed over those of the inner grating when seen with exactly central light. I have tested them several times by the unaided eye and by means of a micrometer in the eye-piece, and always found them to correspond, except when the light was not absolutely central. Also the edge-view confirms their superposition so far as I have been able to make it out, but it is very difficult to get a really good focal image of this part.

P. angulatum has one very obvious peculiarity which I do not remember to have seen mentioned, namely, that at the ends of the valve the grating suddenly changes from the hexagonal to the square type of mesh. This should form a good specific character.

Surirella gemma.—Mixed with *Pleurosigma balticum* on Mr. Capell's slide are numerous specimens of *Surirella gemma*, which,

* Mr. T. F. Smith is of opinion that the outer grating is different in structure from the inner grating, and views of both gratings are given in *The Microscope and its Revelations*, 8th ed. p. 593, pl. 1, figs. 1 and 2. I am not able to confirm this view, for every structural image seen on the outer grating I have also been able to see on the inner grating—it is merely a question of focus and illumination. The "delicate membrane" on the outside of the shell described by Mr. Smith I have already noted under *P. balticum*, so need not make any further remark upon it.

in consequence of having seen the minute pores in *P. balticum*, I eagerly examined, as I was reminded that some four years ago whilst examining *S. gemma* mounted in styrax with a Leitz $\frac{1}{10}$th achromatic oil-immersion objective of 1·3 N.A. I had seen similar pores or dots on the white beads of that diatom. At the time, being very busy with other work and thoroughly accepting the opinion that the black dots usually seen were pores, I paid no attention to what I then saw. Now, however, I examined them with fresh interest and found that in this realgar mount the pores are distinctly visible. To see them, the valve must be resolved into a grating formed of slender, slightly zigzag black bars, with the interspaces divided by very slender transverse partitions into small meshes (the so-called white-dot focus). At a magnification of from 1,800 to 3,000 diameters on some specimens, but not all, a minute dark speck or pore at the centre of every one of the meshes is very clearly visible (figs. 3 and 4); at the same time it is so minute that it requires good eyesight to perceive it, but, as in other cases, becomes accentuated if a small stop be placed in the carrier of the condenser. There is therefore no very great difference in the ultimate structure of this *Surirella* and of *Pleurosigma balticum*, except that in the latter it is the bars parallel to the longer axis of the diatom which are most evident, whilst in *Surirella gemma* the bars transverse to that axis are the most apparent. It must be understood that I refer here only to the fine secondary bars or those of the cell-wall, not to the stout primary bars which form the framework of the diatom and support the cell-wall. The nodes, formed by the junction of the slender partitions with the bars, at another focus produce the appearance of black dots by refraction or diffraction as they do in *Pleurosigma balticum*. One specimen of *S. gemma* on the slide is crumpled up and the bars bent and turned aside so as to show their nature very clearly when sufficiently magnified, and demonstrate that they are exactly of the same character as those of *Pleurosigma balticum*—that is, they are the strengthening bars of the membrane of the diatom. I have been unable to determine whether there is also a membrane over the inner surface of these bars, but think it very probable, in which case the white bead-like appearance will be chambers with minute orifices in their inner and outer wall.

This diatom seems to provide the microscopist with a series of

tests; with lenses having a smaller aperture than about 0 68 N.A. only the primary bars of the framework are visible; with lenses of a larger aperture, the secondary bars (*i.e.* those of the cell-wall) become manifest as very fine lines between the primary bars; finally with lenses of large aperture and at a magnification of not less than 1,800 diameters these fine lines or bars are seen to be connected by finer transverse bars so as to form a ladder-like structure, with a minute pore at the centre of each bead-like space formed by the cross bars, or at another focus the bars can be resolved into the appearance of rows of dots.

Navicula serians.—The structure of the valve of this species seems rather difficult to understand. When I first examined it in search of pores, I found it had a rather coarse grating, with oblong meshes arranged in six to seven rows on each side of the raphe, the longer diameter of the meshes being transverse to the latter. These meshes are closed by a very thin membrane of silex, at the centre of which can be seen, at a magnification of 3,000 diameters, a minute dark dot, as represented at the upper part of fig. 10. This dot I take to be a pore. With central light only a very faint indication of it is seen; but when a small central stop is placed in the condenser it becomes clearly visible. This structure is all that I at first noted. But having re-examined this diatom with great care under all conditions of illumination at my command, I have detected structure which had previously entirely escaped my notice. For I find that if the outer surface of the valve is illuminated by a Leitz dark-ground illuminator and examined at a magnification of not less than 2,000 diameters, without reducing the N.A. by using a funnel-stop, a second grating exterior to and superposed upon that above described can be distinctly seen. This outer grating is evidently extremely transparent and practically invisible by central light, so that it very easily escapes notice. I have found that the easiest way to make it evident is, first to get the membrane of the coarse meshes in focus, as represented at the upper part of fig. 10, then gradually but very slightly raise the lens above that focal plane, until two dark dots appear over each mesh. If these dots are very accurately focused and the dark-ground illuminator manipulated so as to illuminate the diatom with light reflected upon it from the under surface of the cover-glass, the surface of the valve will be found to have the appear-

ance I have tried to represent at the lower part of fig. 10. I believe that each of these dots, or minute meshes as they really are, is closed by an extremely thin membrane of silex, as on one occasion, when using a dim light reflected from the cover-glass upon the diatom, the presence of such a membrane seemed to be very distinctly evident by the light reflected from its surface over each dark spot and nowhere else. But I entirely failed to see the slightest trace of a pore in it, although I think it probable that one exists in each mesh.

Nitzschia scalaris.—When the fine striae on this diatom are magnified up to 3,000 diameters, they are seen to consist of small beads or pearl-like dots of silex, which are either black or white according to illumination. Upon the very thin membrane between each pair of these rows of beads, a row of very minute pores is just discernible, as represented at fig. 11, which is drawn with a camera-lucida, using central light and a green screen. Under the best of circumstances they are exceedingly faint, and I am not at all sure that they are accurately spaced in my drawing, as I found it exceedingly difficult to plot them on paper by means of a camera-lucida; but the drawing is sufficiently accurate to show their position. It requires good eyesight to see them at all, and I do not think they would be visible at a less magnification than 2,500 diameters. The light must be most carefully manipulated, and for my vision I have found them to be most evident in a rather dim light, a glare effaces them; also at a very slight touch of the fine adjustment they instantly vanish. As a test for high powers, manipulative skill and keenness of vision, I think few things can be found more suitable than the resolution of the pores of this diatom when mounted in styrax.

Amphipleura Lindheimeri.—When the surface of this diatom is accurately in focus (not the black-dot view), a fine grating with square meshes is seen, which somewhat resembles that of *Surirella gemma*; the bars transverse to the raphe being straight, whilst those parallel to the raphe form sinuous lines, because the ends of the short partitions which divide the space between each pair of transverse bars into square meshes do not exactly coincide with the ends of the partitions between the adjoining pairs of transverse bars. At a magnification of 3,000 diameters, when the membrane covering the meshes of the

grating shows a somewhat bead-like appearance, a very minute dusky dot, which I take to be a pore, is just discernible in the centre of every one of them, as represented in fig. 12. These pores, I think, are smaller even than those of *Surirella gemma*, and are very difficult to see, unless perhaps to younger eyes, as I judge them to be about the limit of my vision. At a slightly lower focus the nodes formed by the junctions of the transverse and longitudinal bars assume the well-known black-dot appearance, and all trace of the other structure disappears. Doubtless the structure of *A. pellucida* is similar.

Coscinodiscus heliozoides.—I have nothing to remark upon the structure of the diatom to which Mr. Siddall recently gave the above name; but I should like to call the attention of experts to its remarkable similarity to *Stephanodiscus Hantzschianus*. I have not been able to compare the two, but feel sure that *C. heliozoides* belongs to the genus *Stephanodiscus*, and have a suspicion that it and *S. Hantzschianus* are one and the same diatom. A good figure of the latter will be found in the *Deutschen Botanischen Gesellschaft*, 1897, vol. 15, t. 25, fig. 1.

Stauroneis phoenicenteron.—When examined at a magnification of a few hundred diameters, the valve of this diatom is seen to be prettily marked with black dots; but when magnified 2,000 to 3,000 diameters and very accurately focused, the black dots are seen to be optical effects produced by the membrane closing the meshes of the grating. This membrane is slightly sunk below the general level of the surface of the grating so as to form shallow pits. When viewed with the light quite central, without a stop, the bars of the grating appear very much stouter and the meshes smaller and not so well defined as they do by other methods of illumination, and I have quite failed to detect any trace of pores in the membrane by this method. But when oblique illumination is used, either by means of Powell & Lealand's chromatic immersion condenser or by a Leitz dark-ground illuminator, in such a manner that it is reflected from the under surface of the cover-glass upon the diatom, then a pore in the centre of the membrane of each mesh or pit is distinctly perceptible, and the structure has the appearance represented at fig. 14, which is drawn by means of a camera-lucida from a portion of the grating adjoining the "stauros," at a magnification

of 3,000 diameters. The pores are best seen when the light is not very brilliant.

Triceratium favus.—The structure of this diatom, as well as that of several other species, has been described and illustrated in a very interesting article by Floegel in the *Journal of the Royal Microscopical Society*, 1884, vol. 4, p. 665, t. 9, figs. 21 and 22, and by Otto Müller in the *Deutschen Botanischen Gesellschaft*, 1898, vol. 16, p. 387, t. 26, fig. 5, and 1899, vol. 17, p. 435, t. 29, figs. 1 to 5. Both these authors figure and describe the valve as consisting of honeycomb-like hexagonal chambers, which are open at the outer surface and closed by a very thin perforated plate at the inner surface of the shell. Floegel made sections of the valve, and from his drawings of what he saw one would expect his interpretation to be correct. Müller's interpretation is substantially the same. I have not made sections, but from repeated observations of the external appearance of the valve I am convinced that their interpretation is not correct. If the outer surface of the shell of *T. favus* is examined under a binocular, with a $\frac{1}{12}$th oil-immersion objective, using either oblique light or oblique light reflected from the under surface of the cover-glass upon the object (the Leitz dark-ground illuminator, when decentred, acts admirably for this purpose), a thin plate of silex closing the external opening is very distinctly evident, for light-reflections and shadows can be very clearly seen upon it, and are seen to move over its surface when the mirror is slightly moved. The appearance is represented in fig. 15, made from a camera-lucida drawing, in which the outline was made by viewing it under a monocular, with central light, at a magnification of 1,500 diameters, and the shading put in to show its appearance as seen under a binocular at the same magnification with oblique light, the chamber chosen being midway on the slope between the apex of the convexity of the outer surface of the valve and the margin. This closing membrane I believe to be very thin, and probably any section of it that Floegel made would be nearly or quite invisible, and therefore easily overlooked. I fail to detect any pores in it, although I have examined it by several methods of illumination; but at the same time there is a faint indication of some kind of fine-grained surface which may ultimately prove to be pore-structure.

Upon examining the inner surface of the valve at the same

magnification and with oblique illumination, the appearance of the closing plate is as shown at fig. 16, represented for effect as at black-dot focus, and drawn and shaded by the same method as fig. 15. If, however, it is examined by dark-ground illumination, and especially if the illuminator be decentred so as to reflect the light from the under surface of the cover-glass upon the diatom, the closing plates appear to be much more raised than as seen by oblique light and nearly hemispherical; which, however, is the correct appearance I am unable to say. Both forms of illumination distinctly demonstrate that the outer and inner closing plates have their central part raised above their marginal attachment, or, in other words, each closing plate is separated from its neighbours by a furrow. Floegel and Müller, however, both represent the inner plate as perfectly flat and even, and continuous with that of the adjoining chambers, and in their drawings (which I think must be somewhat diagrammatic) of considerable relative thickness. Floegel represents the inner plate as containing small cavities in its substance, closed on all sides. Müller, in the figure he published in 1898, represents the plate as having small perforations through its substance, whilst in that published in 1899 he represents the plate as having small concave pits extending half-way through its substance on the side facing the interior of the diatom. This latter view is, I believe, much more correct than the other two interpretations, for I find that at a magnification of 3,000 diameters, when the light is oblique, or reflected upon it from the inner surface of the cover-glass, so that the plate is of a dull greyish-white colour, it is clearly seen to have pit-like cavities in it closed by a membrane which is probably situated at the other surface of the plate. These pits can be clearly demonstrated by gently moving the mirror, when the shadow formed by the wall of the pit is seen to move round upon the membrane at the bottom of the pit. The appearance of the pits as seen with the light reflected upon them from the under surface of the cover-glass at a magnification of 3,000 diameters, but enlarged to somewhere about 10,000 diameters, is as represented at fig. 17. This membrane under this form of illumination is white, and is probably very thin. When viewed with central light and accurately in focus, it appears more transparent than the thicker plate-substance, and the light shows through it more brightly. But

when examined under dark-ground illumination the reverse seems the case, for then the plate-substance appears to have the transparency of a black sky, and the membrane of the pits reflects the light so as to appear like minute golden stars. It is by some refractive or diffractive property of this membrane that the black-dot appearance is produced, for when the membrane itself is accurately in focus no black dot is seen; but if the focal plane of the lens is above the focus of the membrane, then the black-dot appearance is produced, and appears to me nothing more than a deceptive light effect. From the different appearances of this membrane under different methods of illumination and its contrast with that of the plate, I think it must be of a somewhat different nature. Although I suspect that it is perforated, I have quite failed to perceive any trace of pores in it; higher magnification than I am able to obtain is probably needed for demonstrating anything of that nature.

In conclusion, from the evidence afforded by Mr. Capell's slide and from the observations I have made upon other diatoms—not hastily formed opinions, but based upon many hours' examination under all forms of illumination—it seems clear that we can no longer regard all the black dots usually seen upon diatoms as being pores through the shell, although there may be cases where they are so; for in the cases examined they are certainly nothing more than light effects or shadows, either caused by the nodes of the grating structure, as in *Pleurosigma*; or by the membrane closing the meshes of the grating, as in *Stauroneis*; or by the membrane closing the pits in the cell-wall, as in *Triceratium*.

What I take to be the true pores must be sought for in the thin membrane of silex closing the meshes or pits. If these are not pores, then I do not know where we are to seek for them. I think it must be perfectly obvious, to all who like myself have carefully studied the movements of living diatoms, that there must be openings or pores through the shell communicating with the interior. This seems also conclusively proved in cases where the shell certainly has chambers in its substance, as in *Triceratium favus*, *Pleurosigma angulatum* and others, for in the ordinary process of mounting the medium penetrates easily into the interior of the cavities, and they can also be filled by chemical deposits, which I do not think would be the case if the membranes

closing these cavities were solid, unperforated films of silex; no osmotic theory will account for it.

Also it is quite certain that there is some extrusion of motile living matter from the interior to the exterior of the diatom, which is controlled by the will of the organism.

No one has yet been able to detect any protoplasmic filaments or pseudopodia (other than the crest of protoplasm along the raphe) protruding from the pores of diatoms, and if they are as fine as the pores I have seen would seem to indicate, and as transparent as protoplasm, I doubt if we ever shall see them on the living diatom, as the nearness of their own refractive index to that of water would not provide sufficient contrast to enable us to detect them. Killing and staining do not seem to prove successful in demonstrating anything of the nature of pseudopodia, only the crest at the raphe and a very thin layer of protoplasm sometimes covering the whole shell can be made evident, so far as I have been able to demonstrate it, but it ought not to be lost sight of that there is a possibility that a diatom may be able to speedily retract any protoplasmic matter that it may protrude from its shell or from the film of protoplasm that sometimes covers its shell, so that at the slightest indication of the presence of anything injurious, all external protoplasm of the nature of pseudopodia may be suddenly withdrawn before the diatom is killed. Usually there is no evidence that any living matter is protruded to any distinct distance from the shell, except at the raphe, as any substances taken hold of by a diatom are generally seen in apparent close contact with the shell, although occasionally one is seen dragging a piece of dirt along at a short distance behind it by an invisible thread. But upon a few rare occasions I have witnessed a diatom seize and move pieces of dirt that were at an appreciable distance from the shell, and on one occasion last autumn I was able to measure the interval between the diatom and the dirt. I was observing a large species of *Surirella*, probably *S. biseriata*, which was moving rather quickly across the field, when I saw it seize with invisible hands a large piece of dirt at a little distance from it, and pull it along by its side, without decreasing the distance between itself and the dirt. I at once put on an eye-piece with a micrometer scale on it, and carefully noted the distance separating the dirt and diatom upon the scale, and then substituted a stage micrometer for the diatom and found that

the distance to which the pseudopodia (if I may term them so) extended was between 1/3,000th and 1/4,000th of an inch. After carrying it along across about one-third of the field of view, it released its hold of the dirt, and in doing so I saw it give a very slight but distinct jerk, just as if something had snapped suddenly, for the mass of dirt was very much larger than itself. This observation was made with a $\frac{2}{5}$th lens.

Finally a word as to the pores. It must not be expected that they can be rendered visible in as easy a manner as *Surirella gemma* can be resolved into dots, for they cannot; they are so extremely minute that they are by no means easy to detect. To make them out at all a $\frac{1}{10}$th or $\frac{1}{12}$th oil-immersion of N.A. 1·3 is necessary, with eye-pieces of sufficient power to bring the magnification up to at least 1,000 diameters, and often not less than 2,000 diameters is really required to make the structure clear, combined with very careful manipulation, a most exact arrangement of the light and a fair stock of patience. Some can be seen with central light, but for the most part I have found that the easiest way to render them visible is by means of a Leitz dark-ground illuminator, from which, by decentring it, various modifications of oblique light and light reflected from the under surface of the cover-glass can be obtained. This method of reflecting light upon a diatom from the under surface of the cover-glass may not be generally known, but it can be accomplished by decentring the condenser or dark-ground illuminator, and then raising or lowering it slightly until the right effect is produced. The process is not a difficult operation, but requires a little practice, and very often features can be seen much more clearly by this method than by any other. It is like viewing an object upon which the sun is shining, with the back to the sun. When examining a diatom by means of the Leitz illuminator no funnel-stop must be used in the lens to cut down its aperture. Sometimes a rather dim light is better than a bright one for rendering the structure conspicuous.

The lowest power with which I have been able to see the pores in the films of *Pleurosigma balticum* is Powell & Lealand's excellent $\frac{1}{8}$th water-immersion, with which, in combination with a × 18 eye-piece, they are just perceptible. A Leitz $\frac{1}{10}$th or $\frac{1}{12}$th oil-immersion will also demonstrate them and those of other species, but the lens I have chiefly used has been a Reichert

$\frac{1}{12}$th oil-immersion of N.A. 1·3, on account of its greater magnification, as it is really a $\frac{1}{15}$th, not a true $\frac{1}{12}$th.

Description of Plate 23.

Fig. 1. Part of one of the outer films of the outer grating of *Pleurosigma balticum*, × 3,000. The central part from a camera-lucida drawing, the remainder added to scale from various parts of the films, to show the manner in which the bars project and are held in place by the pore-perforated membrane of silex. Realgar mount, central light, no stop.

Fig. 2. Part of a curved bar from a partly dissolved specimen of *Pleurosigma balticum*, which presents both dorsal and edge views, drawn as seen, to a scale of about 9,000 diameters. Realgar mount, central light, no stop.

Fig. 3. Part of the grating of *Surirella gemma*, × 3,000. Realgar mount, central light, no stop.

Fig. 4. Four meshes of the same enlarged to the scale of 9,000 diameters.

Fig. 5. Fragment of the film overlaying the outer grating of *Pleurosigma angulatum*, × 3,000. Realgar mount, Leitz dark-ground illuminator, without a funnel-stop at the back of the objective.

Fig. 6. Diagrammatic enlargement of the bars of the film over the outer grating of *P. angulatum*, to show the manner in which they appear to overlie one another, drawn to a scale of 6,000 diameters. No pores could be seen when this appearance is visible.

Fig. 7. Outer and inner grating of *P. angulatum* under the film of diamond-shaped meshes, × 3,000. Realgar mount.

Fig. 8. Two meshes of the same enlarged to 9,000 diameters.

Fig. 9. Outer grating of *P. angulatum*, seen at the focus immediately preceding the hexagonal appearance of fig. 7, × 3,000. Realgar mount.

Fig. 10. Fragment of the grating of *Navicula serians*, × 3,000. Picric-piperine mount; upper part showing the coarse inner grating, as seen with central light and a central stop in the condenser, green screen; lower part showing the outer grating superposed upon the coarser grating, as seen illuminated by a Leitz dark-ground illuminator.

Fig. 11. Fragment of the shell of *Nitzschia scalaris*, showing pores, × 3,000. Styrax mount, central light, green screen.

Fig. 12. Fragment of the grating of *Amphipleura Lindheimeri*, × 3,000. Styrax mount, central light, green screen.

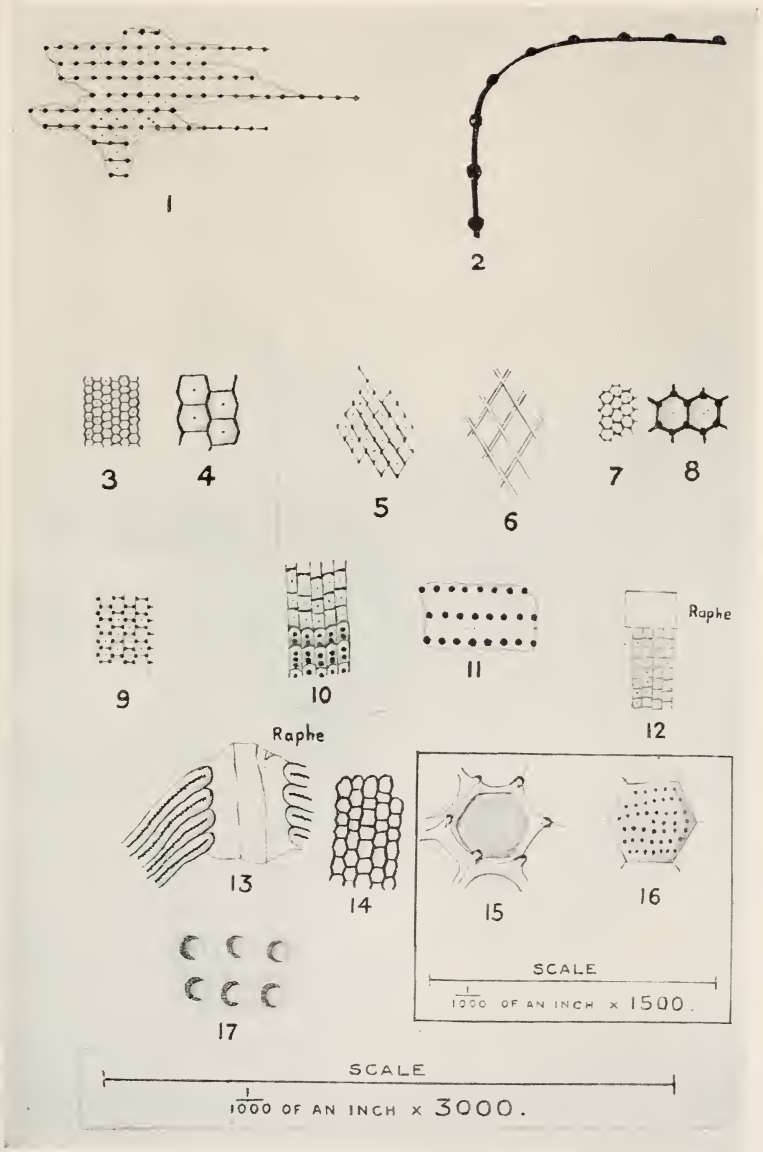
Fig. 13. Fragment of the shell of a small species of *Pinnularia* from the Cherryfield deposit, × 3,000, showing what are believed to be a row of pores down the centre of the outer wall of each cavity. Picric-piperine mount, central light and green screen; can also be seen with dark-ground illumination without a funnel-stop in the lens and no green screen.

Fig. 14. Fragment of the grating of *Stauroneis phoenicenteron*, × 3,000. Picric-piperine mount, oblique illumination by Leitz dark-ground illuminator.

Fig. 15. View of one of the hexagonal cavities of the valve of *Triceratium favus* as seen from the outside of the diatom, showing the membrane which closes it on the outer side, × 1,500. Styrax mount; outline drawn with a camera-lucida as seen under a monocular, shading added as seen under a binocular with oblique illumination.

Fig. 16. View of one of the hexagonal cavities of the valve of *Triceratium favus* as seen from the interior of the diatom, showing the raised appearance of the membrane, × 1,500. Styrax mount, drawn in the same manner as fig. 15.

Fig. 17. Fragment of the membrane shown in fig. 16, drawn as seen at a magnification of 3,000 diameters, but enlarged to about 10,000 diameters, to show the pit-like nature of the dots upon the membrane.



N. E. Brown, *del. ad nat.*

Structure of Diatoms.

NOTICES OF BOOKS.

HANDBOOK OF PHOTOMICROGRAPHY. By H. Lloyd Hind, B.Sc., F.I.C., and W. Brough Randles, B.Sc. $8\frac{1}{2} \times 5\frac{1}{2}$ in., xii + 292 pages, 44 plates and 71 text illustrations. London, 1913: G. Routledge & Sons, Ltd. Price 7*s.* 6*d.* net.

The student of photomicrography, whether he approach the subject from the side of photography or microscopy, can hardly complain of the lack of manuals whose aim is to guide him in this fascinating subject. The photographer, in reading Messrs. Hind and Randles' handbook, may perhaps be surprised that so much space is devoted to details concerning the microscope and its accessories; but he must remember that in order to photograph an object under the microscope it is very essential he should possess the necessary knowledge of the instrument to obtain the best results visually.

Although the subject is treated by the authors in an elementary manner, at the same time, however, the processes are discussed in sufficient detail to be of use in research. A special feature of the book is the very numerous illustrations, and with each photomicrograph reproduced full details are given of the process and apparatus used and the method of developing the negative. This very useful feature enables any special worker to select the best means for his own branch of the subject, whether it be the photography of the minute details of diatoms, the stained sections for use in the histology of plants and animals, or rock sections and crystals under polarised light. The subject of colour photomicrography is dealt with in Chapter XIII. The utility of the Autochrome and Paget plates for registering the appearance of thin rock sections under polarised light was excellently demonstrated at a recent meeting of *The Photomicrographic Society.*

The subject of cinema-micrography is referred to, but this could hardly be dealt with fully in an elementary textbook. In fact, as a means of research it is in its infancy, but fruitful results may be expected in the future in the study of the life-history and movements of micro-organisms.

There are useful formulae and tables at the end of the book and an index. Both authors and publishers may be congratulated on the appearance of the book.

PROCEEDINGS

OF THE

QUEKETT MICROSCOPICAL CLUB.

At the 492nd ordinary meeting of the Club, held on October 28th, 1913, the President, Prof. A. Dendy, D.Sc., F.R.S., in the chair, the minutes of the meeting held on June 24th, 1913, were read and confirmed.

Mr. S. G. H. Knox was balloted for and duly elected a member of the Club.

The Hon. Secretary said they were favoured with the presence of several visitors, to whom he offered a hearty welcome on behalf of the Club.

The President said that members would be sorry to hear that since the last ordinary meeting the Club has sustained the loss of one of our more well-known members: the Right Hon. Sir Ford North, F.R.S., died on October 12th, at the age of eighty-three. He was a Fellow of the Royal Society, and a keen entomologist. He was elected a member of the Club in 1894, became a member of the committee in 1899, and was one of the vice-presidents from February 1901. His patience and experience in directing a meeting when he occupied the chair made him a most valuable member of the Club, and one whose loss will be much regretted.

Mr. E. J. Spitta said that Sir Ford North hardly ever missed attending the meetings of the Club, and he thought that a more charming man never existed. Often in committee he would remain silent for a long time, and would then rap out a very clever opinion on the matter before them. During the four years of his (Mr. Spitta's) presidency he had frequent opportunities of intercourse with Sir Ford North, and on every occasion had found him a courteous friend.

Mr. Spitta then moved: "That the Committee be empowered through the Secretary to convey to the relatives of the late Sir Ford North an expression of their regret and sympathy."

This having been put to the meeting, it was unanimously carried by the members present silently rising.

The list of donations to the Club was read, and the thanks of the members were voted to the donors.

Mr. S. C. Akehurst (Hon. Librarian) read a note on "A Changer for Use with Sub-stage Condensers." The method of using the changer was demonstrated to the members.

Mr. S. C. Akehurst also read a note on "A Trap for Free-swimming Organisms." Two forms of the little piece of apparatus were exhibited, and details demonstrated by drawings on the blackboard.

The President said he had examined the extremely ingenious contrivance for quickly changing the condenser. It was a matter which very strongly appealed to him, as he had often much trouble in changing condensers.

Mr. D. J. Scourfield, referring to the trap for free-swimming organisms, said this method opened new possibilities when dealing with extremely minute organisms. One can get to a certain point with the centrifuge; but it is sometimes desired to go a little further in concentrating. He thought it a very ingenious piece of apparatus.

A paper on "The Gastrotricha," communicated by Mr. James Murray, F.R.S.E., was introduced by Mr. Scourfield, who said that it was just twenty-four years since the subject had previously been brought before the notice of the Club. This was a paper read by T. Spencer on September 27, 1889, on a new species he provisionally named *Polyarthra fusiformis*. This is now *Stylochaeta fusiformis*. Mr. Murray said that he had been reluctant to attempt an introduction to the study of the Gastrotricha, as his knowledge of the group was by no means profound, and had been only recently acquired. The main part of the paper is an annotated bibliography which it was hoped would save students much of the trouble the author had experienced. If the bibliography be too condensed, the student is always liable to suspect that a work omitted from it has not come to the knowledge of the compiler. Here, however, all important general, biological and systematic works known to the author are included, as well as any really important faunistic studies. Every work is given in which new, or supposed new, species or groups of higher value are described. It is unfortunate that the Gastrotricha—which include those old familiar friends of the students of pond-life, *Chaetonotus larus*

and *Ichthydium podura*—have no popular name. Gosse proposed the name of "hairy-backed animalcules." This is entirely unsuitable, since some of the genera are not hairy-backed (Ichthydium, Lepidoderma). Mr. Murray was not able to suggest an appropriate name. The name suggested by the scientific term for the whole group, which embodies almost the only character which they all possess, is unsuitable for popular use. The Gastrotricha are not animals which can be named offhand. The days when we found *Chaetonotus larus* and *Ichthydium podura*, occasionally varied by *C. maximus*, on all our pond-life excursions are over. There is a host of species which have contributed to the records of *C. larus*. These species are all alike to a casual glance, but are distinguished by minute characters—the possession of small branches by certain of the bristles, the form of the minute scales which bear the bristles, etc. Some of these are so delicate that an oil-immersion lens would be needed for their certain determination. The author expressed his thanks to Messrs. Rousselet, Bryce and Starring for assistance given in the preparation of this paper. The paper then goes on to describe the form and structure of the Gastrotricha, their haunts and habits, an historical sketch of the genera, their classification, a key to the genera and a list of the eighty-three species which have been described, notes on the identification of species and on some species Mr. Murray had seen, and concludes with a bibliography of seventy-two items. Mr. Scourfield illustrated his remarks and comments by references to a number of sketches he had drawn on the blackboard.

The President had much appreciated Mr. Scourfield's *résumé* of Mr. Murray's paper. He referred to the "fish-hook" spines and other extraordinary specific characters, which, he thought, could not possibly be explained as due to natural selection. The Club was very much to be congratulated on having such an important paper contributed to the Journal.

Mr. Rousselet said these organisms could be preserved quite well in 5-per-cent. formalin. He remembered Mr. Spencer's paper in 1889 quite well, and had differed from him at the time, and had said *fusiformis* was not a rotifer, but could not then say what it was. The animal was taken at a Club excursion.

On the motion of the President a cordial vote of thanks was

passed to Mr. Murray for his paper and to Mr. Scourfield for giving them so good a *résumé* of it.

Mr. James Grundy described and exhibited "An Improved Form of Cheshire's Apertometer."

Mr. Grundy said that of the value of Mr. Cheshire's form of apertometer there can be no doubt. The aim of Mr. Nelson has been to enable the N.A. values of an objective to be read on the apertometer easily and accurately. Distinctness and clearness of reading have been effected by increasing the number of marked values of N.A. from 9 to 22 without the confusion that overcrowding of the lines would entail. To accomplish this, short arcs of circles are used instead of whole circles. A valuable property of these is the clear visibility of the ends or edges of the arcs: they are seen more distinctly than complete circles would be. The contrast between the white ground and the short black lines favours this. The exterior edges of the arcs denote the N.A., and thus give most convenient, accurate, and definite positions for reading.

Mr. F. J. Cheshire said it might interest members to know that he described his apertometer before the Club some ten years ago. When Zeiss first issued Abbe's form, it was marked to read only to 0·05. In a paper defending this marking, read before the R.M.S. in 1880, Abbe dealt with the accuracy it was necessary to strive for. On the Zeiss apertometer it is possible to read to $\frac{1}{2}$ per cent.; but blue rays alone will give a difference of 1 per cent. over a reading taken with red light, so that the maximum accuracy it was advisable to attempt to obtain was 1 per cent. Mr. Cheshire thought that one point in Mr. Nelson's diagram largely vitiates the advantages given by a greater number of fiducial lines—that is, that the fiducial edge in the diagram is the outer edge of the line; and, again, the lines are of varying thickness. There are twenty-two edges of lines on the diagram with no fiducial value. He himself thought that his original form was not capable of further accuracy. Mr. Cheshire then described, and subsequently demonstrated, another method of measuring N.A., which he considered an improvement on the older form.

A visitor—Mr. M. A. Ainslie, R.N.—said that experience in the use of both the original form of Cheshire's apertometer and the modification thereof recently suggested by Mr. Nelson has

revealed one or two difficulties in connection with the reading of the instrument—that is, if any accuracy in the second decimal place is required. The first difficulty is due to the fact that in Mr. Cheshire's instrument we have to interpolate or estimate between two divisions on a scale, one of which is not visible, being outside (apparently) the margin of the back lens of the objective. This renders the estimation of the second place of decimals in the N.A. uncertain, and although Mr. Nelson's modification of the original instrument is somewhat better in this respect, yet the very means adopted to improve the reading—namely, the introduction of a large number of additional circles—is likely to confuse the diagram and bewilder the observer. In either the old form or the new of Cheshire's instrument, a count has to be made of concentric circles—a thing which, simple as it may seem, is peculiarly liable to confuse the eye, so that it is only after counting several times that one feels certain that the number is, say, eight, and not seven.

Mr. Ainslie exhibited and described a new method of reading the N.A. of an objective.

The President said the Club was much indebted to Mr. Ainslie for his communication, and also to Mr. Cheshire and Mr. Grundy, to whom the thanks of the meeting were unanimously voted.

At the 493rd ordinary meeting of the Club, held on November 25th, 1913, the President, Prof. A. Dendy, D.Sc., F.R.S., in the chair, the minutes of the meeting held on October 28th, 1913, were read and confirmed.

Messrs. W. M. Bale, B. Shepherd, H. Dobell, E. W. Ramsay, M. R. Liddon, A. Panichelli, Robert Young, W. G. Tilling, and E. J. E. Creese were balloted for and duly elected members of the Club.

The President read a letter from the nephew of the late Sir Ford North, which was in reply to the vote of sympathy passed at the last meeting.

Mr. C. E. Heath, F.R.M.S., brought before the notice of the meeting a device for preventing damage to objective or slide, especially when the higher powers are used, in cases where the microscope is liable to unskilful usage, as, *e.g.*, at soirées. A small piece of thin metal—steel was suggested—is taken, having

a hole in it of such a size as to permit of the screw-end of an objective passing through it up to its flange. In use the plate is placed over the end of the nose-piece, and the objective screwed home through it. To a projecting portion of the metal plate is fitted a short length of brass tube or rod—say $\frac{1}{4}$ in. diameter, which has been tapped internally, the direction of the tube being parallel to the optic axis, and just clear of the objective. A fine screw (25 threads to an inch) is fitted to the tube, and at the lower end is provided with a milled head. The microscope is focused in the usual way, and the screw then screwed down until it is in contact with the stage clear of the cover-glass, and so prevents any movement of the body, and possible damage. If required, a small amount of slack may be left for possible focusing by visitors who can use a microscope.

The President described "A Red-Water Phenomenon due to Euglena." He had noticed a curious appearance in a pond near Manchester: the water was of a brilliant red colour. This, on examination, proved to be due to Euglena, which formed quite a thick scum of the red colour. The colour was confined to the surface, and had a dry, powdery appearance that was very noticeable. Microscopic examination showed the Euglena to be of a large species, and the red coloration to be due to the replacement of the chlorophyll by haematochrome. The main mass of the body was coloured. Those floating on the surface were in a resting condition; but, at the bottom, all were actively swimming about. There was apparently no intermediate stage, and at once the question arose: How did the organisms get from the bottom to the top of the pond? It was found that the Euglenae at the bottom of the pond secreted large quantities of mucilage. The organism, in the presence of sunlight, gave off bubbles of oxygen, which became entangled in the mass of mucilage, and presently carried the mass to the surface, trailing Euglenae after it, so that they were collected at, and formed a scum on, the surface. The colour of the scum changed during the day, from red in the morning to green in the afternoon, the actual change from one to the other being accomplished in about half an hour. Cunningham had observed similar changes in *Euglena viridis*, near Calcutta. He records the scum as bright red in the morning dull red at midday, and green in the evening, and by sunset an intensely vivid green. The reverse took place just about dawn,

so that at sunrise the pond scum was brilliant red again. The President asked if any members had seen a similar appearance.

Mr. C. F. Rousselet, when in South Africa with the British Association in 1905, had noted near the Matoppo hills a similar red Euglena, which he had not before seen.

The Hon. Sec. paid considerable attention to the "Breaking of the Meres," but had never seen red Euglena. He had observed red scum, due to other causes. The phenomenon noticed by the President was, however, not unique in this country. Some years ago he had received some "red scum" material from Norfolk, which was definitely identified as Euglena. The organisms were crowded in their middle region with starch grains, and starch in such a form that it was not affected by iodine.

Mr. A. E. Hilton asked whether the red colour indicated the decay of the chlorophyll formed during the previous day.

The President did not think that the change from green to red indicated any process of decay—this change of colour was not unique in Nature, as the snow plant could be obtained both red and green, and apparently the change was due to nitrogen starvation. He found this to be the probable cause when he had two jars side by side, one red and the other green, and a fly had fallen into one jar and had decayed; the slightest trace of nitrogenous food was sufficient to cause the change, which he thought could not be regarded as a product of decomposition. Dr. Cunningham thought that both kinds of pigment were present at the same time, but that they were differently placed when the change of colour was observed; but whether this was the sole reason for the change in the Euglenae was not certain.

Mr. James Burton (Hon. Secretary) read a short paper, "On the Disc-like Termination of the Flagellum in certain Euglenae."

Mr. James Burton also read a note on "A Method of Marking a Given Object on a Mounted Slide."

Mr. M. Blood said he usually put a spot of ink on the bright spot of light formed on the slide by a high-power condenser, and when it was dry, scraped the centre away.

Mr. Spitta, after finding and centring the object in the field, replaced the objective with a dummy of similar size, on to the lower end of which had been fastened a rubber letter O, such as is to be obtained in small movable-type printing outfits. The letter is

inked, and gently lowered on to the slide. He had found this method quite satisfactory.

Mr. James Grundy read a paper communicated by Mr. E. M. Nelson on "The Measurement of the Initial Magnifying Powers of Objectives." Mr. Grundy added a few notes in amplification and explanation of some points in Mr. Nelson's paper, which he illustrated with blackboard diagrams.

A vote of thanks to Mr. Grundy was carried unanimously.

At the 494th ordinary meeting of the Club, held on December 23rd, 1913, Mr. D. J. Scourfield, F.Z.S., F.R.M.S., Vice-President, in the chair, the minutes of the meeting held on November 25th, 1913, were read and confirmed.

Messrs. M. A. Ainslie, R. A. Saunders, T. B. Lock, F. S. Mumford, A. Green, H. F. W. Sprenger, W. D. Deed and J. H. North were balloted for and duly elected members of the Club.

A letter was read from the Royal Microscopical Society enclosing a copy of a resolution passed by their Council, thanking the members of the Q.M.C. who exhibited at their Conversazione on November 19th.

Mr. B. M. Draper read a paper on a new live box for the exhibition of flies and other large objects under low powers of the microscope—the article itself being exhibited in the room under a Greenhough binocular.

Mr. B. M. Draper also read a paper describing a new stop for obtaining dark-ground illumination with the Greenhough binocular—the subject being illustrated by the exhibition of the stop and by a diagram upon the blackboard.

The Chairman thought the live box well adapted for showing large objects, and inquired if any means were adopted for confining the insects or controlling their movements whilst under observation.

Mr. Draper said there was no other means of controlling the movement of the objects except by the use of a small cell, but the power used being a low one, the whole cell was generally in the field at the same time; and in answer to a question by Mr. Rousselet, he said that the cover of the cell was only held down by its own weight, but it was prevented from slipping sideways by the upright pins mentioned in the paper.

The thanks of the meeting were voted to Mr. Draper for his papers.

Mr. W. R. Traviss exhibited under microscopes two fragments of quartz crystals. Referring to one of the mounts, he said it showed a series of seven faint lines across the field, parallel, but not equally spaced. He suggested that the lines at one time were respectively the outer surfaces of the crystal. The plane of this particular surface in the mount referred to was at right angles to the plane of the microscope stage, so that by focusing down one could look along this plane. It was then noted that this "old crystal surface" was covered with a number of very small crystals, or débris, which had been deposited on this plane. Presently the crystal went on growing, and again a period of rest and more débris deposited or formed. This was repeated seven times, but the exterior face was quite smooth.

Then as to the occasional presence of contained bubbles of liquid in quartz (and other) crystals. It was suggested that it was possible that they were formed by a bubble of gas adhering to perhaps the under surface of a growing crystal, and material being deposited round and over it.

Some discussion followed on liquid enclosures in crystals and the nature and method of identification of the gases contained. The chairman drew attention to a paper by Mr. Ashe on the effects of temperature on enclosed liquids. (*Journ. Q. M. C.*, Ser. 2, Vol. VIII., pp. 545–8, pl. 28.)

Mr. E. M. Nelson sent a note on a peculiar form of diatom. During an examination with dark-ground illumination of Mr. Siddall's filaments on some Coscinodisci in a diatom gathering, mounted and kindly given me by Mr. Chaffey, a small portion of sandy grit was found to have similar filaments protruding from it. Its colour was a golden yellow, the same as the sandy grit usually seen in this kind of slide, which contains diatoms mounted in sea-water in their natural state. The dark-ground illuminator was removed, and when the object was examined by an oil-immersion $\frac{1}{8}$th with transmitted light from an achromatic condenser, the green chlorophyll pustules of a diatom could just be made out inside the conglomerated mass of sandy grit. A search was then made over the slide, and three or four other similar specimens were found. So it appears, then, that there is a "caddis-worm" form of a diatom. What species this diatom

may be no one can say, for it cannot be seen with sufficient distinctness for identification. Probably in its cleaned state it may be a very common and well-known form, but had it not been for its filaments, its presence in these sandy conglomerations would never have been suspected. Other species of diatoms on this slide were quite free from sandy grit.

Mr. Nelson also sent a note on *Amphipleura Lindheimeri*.

At the 495th ordinary meeting of the Club, held on January 27th, the President, Prof. A. Dendy, D.Sc., F.R.S., in the chair, the minutes of the meeting held on December 23rd, 1913, were read and confirmed.

Messrs. H. A. Gee, G. H. Shelley, A. Walker, the Rev. G. H. Nall, Lieut.-Col. J. Clibborn and L. E. Harris were balloted for and duly elected members of the Club.

The list of nominations by the Committee of officers for the ensuing year was then made—there being no change from that elected last year.

The President having mentioned that four members of the Committee—Messrs. Wilson, Heron-Allen, Bryce and Caffyn—would retire by rotation, but were eligible for re-election, except Mr. Caffyn, who did not wish to serve again, asked for nominations of members to fill the vacancies created.

The following gentlemen were thereupon nominated: Messrs. Heron-Allen, Wilson, Bryce, Gabb, A. Morley Jones and Todd, whose names would appear on the voting paper at the next ordinary meeting.

Mr. A. E. Hilton was then elected as Auditor on behalf of the members.

Mr. S. C. Akehurst (Hon. Librarian) read "Some Remarks on Sub-stage Illumination"; the subject was illustrated by a number of photographs projected upon the screen.

Mr. T. A. O'Donohoe read a paper, entitled "An Attempt to resolve *Pinnularia nobilis*." This was illustrated by photographs projected upon the screen.

Mr. M. A. Ainslie said that the whole question of diffraction spectra was of course of vital importance in the resolution of any fine structure, and in many cases it could not be done with a dry lens. By means of diagrams drawn on the blackboard as he pro-

ceeded, the speaker showed the effects of diffraction spectra under varied conditions. In using annular illumination they were using a number of central cones of illumination overlapping to form the annular. He also pointed out the danger of using annular illumination unless great care was exercised as to the tube length.

Mr. Blood said it was extremely easy to resolve diatoms with a central stop—in which case they were merely seeing the image of the stop. In many objectives the central portion and the extreme edge were over corrected, but the intermediate zone was quite right.

Mr. Brown said he had been examining *Pinnularia nobilis* for the last forty years, and thought he had obtained a resolution of it, but not the same as that described by Mr. O'Donohoe. For a long time he was unable to get any resolution, but he believed he had now done so, and hoped shortly to read a paper on the subject.

Mr. Akehurst explained that the photographs shown in illustration of his paper were taken to show the contrast between the ordinary and the new method of illumination with central stop below the condenser, but without cutting down the N.A. of the objective.

Votes of thanks were cordially passed to Mr. Akehurst and Mr. O'Donohoe for their papers.

In place of the usual monthly conversational meeting, a Conversazione was held on February 10th, in the Great Hall, King's College, by kind permission of the Principal. Nearly five hundred members and visitors were present, and about 170 microscopes, besides other apparatus, were on exhibition. It is not possible to give a complete list of the objects shown; but among others may be mentioned a number of coloured drawings of water-mites, including a series of fifteen figures illustrating the life-history of *Hydrachna globosa* (de Geer), by C. D. Soar; foraminifera under microscopes, and material from the sea-bottom in various stages of preparation, by Messrs. Heron-Allen and Earland; living rotifers by Messrs. Bryce, Dunstall, Rousselet, Scourfield and others; stereophoto-micrographs by Messrs. A. E. Smith and Taverner; photomicrographic apparatus and some sixty natural-colour lantern-slides by E. Cuzner; some fine photomicrographs in colour of polarised rock sections by Messrs. Caffyn and Ogilvy.

Mr. H. F. Angus (H. F. Angus & Co.) showed the Reichert demonstration and comparison eye-piece for comparing the fields from two microscopes in one eye-piece, in which the field is divided laterally, Akehurst's phototropic pond-life trap, Draper's all-glass live box, the Finlayson revolving disc for the exhibition of a series of opaque objects, Heath's objective-guard, etc.

Mr. Lees Curties (C. Baker) had on view several Greenhough binocular microscopes, multicolour illumination of crystals, and three forms of the Cheshire apertometer.

Mr. C. Beck (R. & J. Beck) exhibited the new model high-power binocular, employing a $\frac{1}{12}$th oil-immersion objective, with a very simple and efficient adjustment for inter-pupillary distance.

Mr. J. W. Ogilvy (E. Leitz) showed several new short-tube high-power binoculars employing a $\frac{1}{12}$th oil-immersion objective; a comparison eye-piece for comparing simultaneously complete fields of two microscopes; and several examples of the Greenhough binocular—one especially adapted for metallurgical work.

Mr. F. W. W. Baker (W. Watson & Sons) exhibited a new model Van Heurck, with $2\frac{1}{2}$ in. movement to the stage, and complete rotation, also a new workshop metallurgical microscope and some twenty microscopes with various objects, including a series of seven illustrating the development of the chick from twenty-four hours to four days.

During the evening a lantern lecture was given in the large theatre by Mr. F. W. Watson Baker (Watson & Sons) on "Some Microscopical Hows," and subsequently Mr. C. Lees Curties (C. Baker) gave a lantern demonstration, in the same place, of natural-colour photographs and photomicrographs of miscellaneous and microscopic objects prepared by the Paget process. Both lectures were well attended and much appreciated.

Of late years the club has not held conversaziones, and during the evening the wish was several times expressed that such gatherings should be more frequent, and certainly that no long interval should elapse between this and the next. (The last conversazione was held nearly seventeen years ago—on May 4th, 1897—in the smaller Queen's Hall.)

At the 496th ordinary meeting of the Club held on February 24th, which was also the forty-eighth annual general meeting, the President, Prof. A. Dendy, D.Sc., F.R.S., in the chair the minutes of the meeting held on January 27th were read and confirmed.

Messrs. A. C. Gooding and Raymond Finlayson were balloted for and duly elected members of the Club.

The list of donations to the Club were read, and the thanks of the members voted to the donors.

Mr. N. E. Brown and Mr. F. W. Watson Baker having been appointed scrutineers, the ballot for the election of officers and Council for the ensuing year was proceeded with ; it being subsequently announced that the following gentlemen had been elected as

President . . .	Prof. Arthur Dendy, D.Sc., F.R.S.
Four Vice-Presidents	C. F. Rousselet, F.R.M.S. E. J. Spitta, L.R.C.P., M.R.C.S., F.R.A.S D. J. Scourfield, F.Z.S., F.R.M.S. Prof. E. A. Minchin, M.A., Ph.D., F.R.S.
Treasurer . . .	Frederick J. Perks.
Secretary . . .	James Burton.
Assistant Secretary	J. H. Pledge, F.R.M.S.
Foreign Secretary .	C. F. Rousselet, F.R.M.S.
Reporter	R. T. Lewis, F.R.M.S.
Librarian . . .	S. C. Akehurst, F.R.M.S.
Curator	C. J. Sidwell, F.R.M.S.
Editor	A. W. Sheppard, F.Z.S., F.R.M.S.
Four Members of Committee.	A. Morley Jones. E. Heron-Allen, F.L.S., F.Z.S., F.R.M.S. J. Wilson, F.R.M.S. D. Bryce.

The Hon. Secretary read the Committee's forty-eighth annual report. Fifty-five new members were elected during the past year, and the total number is now 441.

The Hon. Curator reported that 2,000 slides had been borrowed by members, and that 192 preparations had been added to the collection during the past twelve months.

The Hon. Treasurer presented the Annual Statement of

Accounts and the Balance Sheet for 1913, which had been duly audited and found correct.

The adoption of the Committee's report and the Balance Sheet was moved by Mr. A. Morley Jones and seconded by Mr. Morland and carried unanimously.

Mr. D. J. Scourfield, F.Z.S., F.R.M.S., Vice-President, having taken the chair, the annual address was delivered by the President, who took as his subject "Organisms and Origins."

The usual votes of thanks to the President for his address, and to the officers of the Club for their services during the past year, were carried by the meeting. A special vote of thanks was passed to the Hon. Secretary and to Mr. J. Grundy for their services in so successfully organising the recent conversazione.

FORTY-EIGHTH ANNUAL REPORT.

Your Committee are glad to be able to assure the Club of its continued prosperity. During the year ending December 31st, 1913, fifty-five new members were elected; this number has been equalled only once, and exceeded only once—when there were fifty-seven elected—during the recent years of which any record has been found. Eleven have resigned, and four were lost by death, leaving the present number 441. Among those lost by death should be mentioned the Right Hon. Sir Ford North, for some years a Vice-President and a valued member of the Club. An obituary notice appeared in the November number of the Journal.

Both the Ordinary and Gossip Meetings have been well attended, in fact on several occasions the number present was somewhat more than the capacity of the room would accommodate with a due regard to comfort.

The papers and notes read and exhibits contributed during the year were as follows:

Jan. W. M. Bale, F.R.M.S., of Victoria, Australia. Notes on some of the Discoid Diatoms. Communicated by the President.

,, H. Whitehead, B.Sc. British Freshwater Rhabdocoelida (Planarians). Communicated by J. Wilson.

,, C. F. Rousselet, F.R.M.S. The Rotifera of Devil's Lake: Description of a New Brachionus.

,, E. M. Nelson, F.R.M.S. Note on *Pleurosigma angulatum*; Note on a Coloured Coma observed in examining *A. Ralfsii*.

Feb. Prof. A. Dendy, D.Sc., F.R.S. By-products of Organic Evolution. Presidential Address.

March. E. Heron-Allen, F.Z.S., F.L.S., and A. Earland, F.R.M.S. On some Foraminifera from the Southern Area of the North Sea, dredged by the Fisheries cruiser *Huxley*.

,, D. Bryce. Five New Species of Bdelloid Rotifers.

April. C. D. Soar, F.L.S., F.R.M.S. Two New Species of Water-mites.

„ G. T. Harris. The Collection and Preservation of the Hydroida.

May. T. A. O'Donohoe. The Minute Structure of *Coscinodiscus asteromphalus* and of two Species of Pleurosigma.

June. H. Sidebottom. The Lagenae of the South-West Pacific.

„ E. M. Nelson, F.R.M.S. On a New Method of Measuring the Magnifying Power of an Objective.

Oct. James Murray, F.R.S.E. The Gastrotricha.

„ E. M. Nelson, F.R.M.S. Note on an Improved Form of Apertometer.

Nov. James Burton. On the Disc-like Termination of the Flagellum in some Euglenae.

„ James Burton. On a Method of Marking a Given Object on a Mounted Slide for Future Reference.

„ E. M. Nelson, F.R.M.S. On the Measurement of the Initial Magnification of Objectives.

Dec. B. M. Draper. On Dark-ground Illumination with the Greenhough Binocular.

At the Ordinary Meetings the following slides and apparatus were exhibited:

Jan. W. Watson Baker. New Model Microscope, having a Side-screw Fine Adjustment, and New Objective Changer, etc.

„ A. A. C. Eliot Merlin, F.R.M.S. Photomicrographs of *Coscinodiscus heliozoides*, showing Pseudopodia.

March. A. A. C. Eliot Merlin, F.R.M.S. Five Photomicrographs taken at × 320 of various Diatoms.

April. Presented by G. T. Harris. Mounted Hydrozoa, exhibited under Microscopes by Messrs. H. F. Angus & Co.

May. J. Watson, a visitor. A Slide showing Multiple Images formed by the Cornea of the Eye of a Bee.

„ E. Pitt. Various Microtomes exhibited and explained, with Demonstration of Ribbon Section-cutting.

June. A. A. C. Eliot Merlin, F.R.M.S. Photomicrograph of Foot of Ceylon Spider.

,, E. M. Nelson, F.R.M.S. A Slide of Green Trap showing Structure resembling Vegetable Tissue.

,, W. Traviss. Apparatus for Use in Pond Hunting, enabling a Sample of Water to be obtained at any desired Depth.

,, James Grundy. Apparatus for use in connection with E. M. Nelson's paper "On a Method of Measuring the Magnifying Power of an Objective."

Oct. S. C. Akehurst. A Changer for Sub-stage Condensers.

,, S. C. Akehurst. Trap for Minute Free-swimming Organisms.

,, Messrs. Grundy, Cheshire and Ainslie. Various Apertometers.

Nov. C. E. Heath, F.R.M.S. Objective Guard for Preventing Damage to High-power Objectives.

Dec. B. M. Draper. A New Form of Transparent "Live Box" for the Exhibition of Living Organisms, chiefly Insects. Also a Special Form of Stop for Dark-ground Illumination with a Greenhough Binocular.

,, W. Traviss. Specimens of Quartz showing under the Microscope a Laminated Structure.

Your Committee feel that the Club is greatly to be congratulated on the inclusion in its Journal of such valuable papers. Not only is their publication in our Proceedings an honour to the Club, but the actual value of the communications as a contribution to science, and especially to that always difficult and often little-appreciated subject, classification, makes the Journal a standard work of reference. The Club has also been the means of making known and recording a number of new species among the Rotifera, the Entomostraca, and Water-mites, by members who are authorities in these several classes. While thanking those members who have contributed to the success of the Club, the Committee would take this opportunity of urging upon others the great advantage of bringing before the Club subjects of interest in the form of short papers or notes, and the profit they would themselves obtain by putting their knowledge into the concrete and definite shape required for this purpose. The

Committee at the same time wish it to be remembered that one of the foremost aims of the Club is to assist the amateur and the beginner, both by providing papers of a somewhat elementary character, and by assuring them that, particularly at the Gossip Meetings, they will find friends willing and anxious to assist them in their efforts in gaining experience in the best methods of using their instruments, and in the task of identifying specimens.

The Librarian reports that there has been a fair demand for books during the year, but somewhat less than that for 1912. The card index and the numbering and rearrangement of the books are nearly completed, and the path cleared for commencing the final details of the new edition of the Catalogue. The thanks of the Club are due to Messrs. Caffyn, Todd and L. C. Bennett for the great amount of assistance they have given the Librarian in these matters.

During the year under review the following volumes have been added :

LIST OF BOOKS PURCHASED SINCE JANUARY 1913.

British Parasitic Copepoda. T. & A. Scott. Vols I. and II. Ray Society.

Bibliography of the Tunicata, 1469—1910. J. Hopkinson. Ray Society.

Schmidt's Atlas der Diatomaceen-kunde. 4 Vols.

Light. (For Students) Edwin Edser.

British Rust Fungi. N. B. Grove.

LIST OF BOOKS PRESENTED SINCE JANUARY 1913.

Presented by the Author, Dr. Eugène Penard :

Nouvelles recherches sur les Amebes du Groupe Terricola.

Presented by the Publisher, John Murray :

Problems of Life and Reproduction . . Marcus Hartog.

Presented by J. Burton :

Das Phytoplankton des Süsswassers.

Presented by the Author, HENRY WHITEHEAD.

BRITISH FRESHWATER LEECHES.

Presented by PROF. ARTHUR DENDY :

CLASSIFICATION AND PHYLOGENY OF THE CALCAREOUS SPONGES . . . Arthur Dendy, D.Sc., F.R.S., and R. W. Harold Row, B.Sc.

With a reference list of all the described species systematically arranged.

Presented by the Author, CHARLES JANET, LIMOGES :

LE VOLVOX AND OTHER PAPERS.

Presented by the Authors, E. HERON-ALLEN and A. EARLAND.

CLARE ISLAND SURVEY : Royal Irish Academy.

Part 64, Foraminifera.

Presented by the Author, J. W. GORDON :

DIFFRACTION IMAGES.

During the year ending December 1913 the Library has received the following publications :

Quarterly Journal of Microscopical Science.
Victorian Naturalist.
Mikrokosmos.
Royal Microscopical Society.
British Association.
Royal Institution.
Geologists' Association.
Manchester Literary and Philosophical Society.
Hertfordshire Natural History Society.
Birmingham Natural History and Philosophical Society.
Botanical Society of Edinburgh.
Glasgow Naturalists' Society.
Croydon Natural History Society.
Indian Museum (Calcutta).
Royal Society of New South Wales.
American Microscopical Society.
Smithsonian Institution.
Academy of Natural Science, Philadelphia.

Missouri Botanic Garden.
Philippine Journal of Science.
Bergen Museum.
Lloyd Library, Cincinnati.
United States National Herbarium.
Royal Society. Series B.
Natural History Society of Glasgow.
Zoologisch-botanischen Gesellschaft, Wien.
Redia.
United States National Museum.
Nuova Notarisia.
Nyt Magazine.
Liverpool Microscopical Society.
Nova Scotian Institute of Sciences.
Royal Dublin Society.
University of California.
Illinois State Laboratory of Natural History.
Société Royale de Botanique de Belgique.
Brighton and Hove Natural History and Philosophical Society.
Essex Naturalist.
Edinburgh Royal Botanic Garden.
Northumberland and Durham Natural History Society.
Torquay Natural History Society.

There were twelve Excursions during the year, which were well attended, the average number present being 20·8. That to the Botanic Gardens had the most numerous visitors, namely 35, and second to that the grounds of Syon House, Isleworth, with 33. Though no new species appear to have been recorded at the outings, abundant and interesting material was acquired, and as always the Excursions were marked by a spirit of comradeship and social friendliness, as well as being an opportunity for scientific acquisition. It may perhaps be pointed out that scarcely as much use is made of the results of the excursions on the subsequent Gossip Meetings as is desirable. Our thanks are due to the officers of the Botanic Gardens, the East London Water Works, and the Surrey Commercial Docks, for their kindness in allowing the Club to visit their enclosures for collecting, and to the Duke of Northumberland for permitting, through the

kind intervention of his agent, the successful visit to the grounds of Syon House. The objects exhibited at the Gossip Meetings have been interesting and sometimes noteworthy, but it may be well to impress upon new members, and beginners especially, that all should make an effort to bring a microscope and some object for display on these occasions. Not only is this a duty owed to their fellows, but a distinct advantage to themselves; they thus become expert in the use of their instruments and in the arrangement of their specimens.

The work of the Curator, carried on for so many years, recently under great difficulty owing to ill health, and to the insufficient space at his command, is beyond all praise, and the best thanks of the Club are hereby tendered to him for his self-denying labours. The Curator reports that all slides and apparatus in his charge are in good condition, and during the past year a great deal of time has been spent in revision and amalgamation of the collections. There has been a considerable increase in the number of preparations borrowed, upwards of 2,000 having gone out, and even then the number has been unavoidably restricted owing to cramped storage accommodation. 192 slides have been added, 72 of them by purchase. The beautiful physiological preparations, accompanied by descriptive letterpress and illustrations, issued by Dr. Sigmund, of which six series have been added, have been in great request. A gap has been filled by the presentation of a series of slides, with illustrated description, by Mr. Whitehead, of Turbellarian Worms, a group previously unrepresented in the cabinets. A type collection of Hydrozoa, presented by Mr. Harris, has been put to practical use, and, now that his accompanying paper has been printed in the Journal, is likely to be still further in demand. It is hoped by the issue of additional descriptive sets to still further increase the usefulness of the cabinets from an educational point of view. With the kind co-operation of Mr. Vogeler the Curator has been able to issue a supplementary list of part of the botanical preparations added since the general catalogue was printed. The hearty thanks of the Club are due to Mr. Vogeler for his kind services in printing, also to Mr. Bestow for general assistance rendered the Curator, and to the various donors of slides. The Committee desires to thank the officers generally for the interest they have evinced, and the often hard work they have undertaken in carrying on the

business of the Club so successfully. The thanks of the Club are due to the editors of *The English Mechanic* and of *Knowledge* for the reports of the proceedings published in their papers.

Finally the Committee feel that the Club may look forward with all confidence to the future. Enthusiasm and work are the means for continuing and increasing the success that has attended it from its commencement, and also the means of enabling us next year to celebrate the Jubilee of its foundation in 1865, by men some of whom happily are still with us to note with pride the growth and vitality shown by the Club they inaugurated almost half a century ago.

THE TREASURER IN ACCOUNT WITH THE QUEKETT MICROSCOPICAL CLUB

Dr. *For the year ending December 31st, 1913.* Cr.

	£	s.	d.		£	s.	d.
To Balance from 1912	250	11	7	By Rent	75	0	0
„ Subscriptions 166 10 0				„ Expenses of *Journal* 126 18 11			
„ 1 Life Subscription 10 0 0				Less Contribution by Mr. Sidebottom 5 0 0	121	18	11
	176	10	0	„ Postages, etc.	5	0	10
„ Dividends on Investments	12	14	4	„ Printing and Stationery	11	1	4
„ Sales of *Journal*	14	18	2	„ Attendant	6	1	3
„ Sales of Catalogues	0	18	0	„ Petty Expenses	2	19	0
„ Advertisements	8	0	9	„ Books, etc.	27	9	6
„ Sale of Books	1	0	0	„ *English Mechanic*	6	14	2
				„ Balance in hand	208	7	10
	£464	12	10		£464	12	10

INVESTMENTS.

	£	s.	d.
2½ per cent. Consols	200	0	0
Metropolitan Water Board Stock	100	0	0
Metropolitan Consolidated Stock	100	0	0
2½ per cent. Annuities, 1905	100	0	0

We have examined the above Statement of Income and Expenditure and compared the same with the Vouchers in the possession of the Treasurer, and have verified the Investments at the Bank of England, and find the same correct.

February 24th, 1914.

ALFRED E. HILTON
J. WILSON } *Auditors.*

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A NEW OBJECT GLASS BY ZEISS, AND A NEW METHOD OF ILLUMINATION.

By Edward M. Nelson, F.R.M.S.

(*Read March 24th*, 1914.)

Figs. 1–3.

An Object Glass upon an entirely new plan has been brought out by the firm of Carl Zeiss. This lens has not yet been catalogued, but as it will undoubtedly effect a considerable change in the construction and use of microscope objectives a short account of it may prove of interest to the Club.

The object glass is a short tube oil-immersion $\frac{1}{4}$ of ·9 N.A. Upon taking it out of its black box the first thing that will be noticed is that it is nickeled all over, and the next is that the front lens is set in a push tube, and not screwed up as usual; these two new departures from the usual type are also found in the oil-immersion $\frac{1}{12}$th recently issued by this firm.

In very early times objectives were made on this plan. Both Ross and Smith, before 1840, used to screw the front lens to a tube, which was pushed on to another holding the back lenses; this tube was then rotated until the best point was found, when a small screw was put in at the side to keep the tube in that position.

This form of construction has gone on continuously to the present day, especially in the cheaper series of objectives, while the more expensive ones, including oil-immersions, have had the cells holding the lenses screwed into their proper positions. But this type of objective, so far as I am aware, for an oil-immersion is quite new, as also is an oil-immersion with a N.A. of less than 1·0. Now with regard to the performance of this lens, the corrections are very perfect; although no fluorite is used in its construction it is very nearly apochromatic, and shows a considerable advance over semi-apochromatism, for only a slight trace of outstanding blue can be seen.

The defining power of this objective is quite remarkable, for it surpasses all object glasses of similar aperture I have seen.

On a Möller's Probe-platte of 60 diatoms all are resolved except

the two specimens of *Amphipleura pellucida*. The next most difficult diatom to the *Amphipleura* is the *Nitzschia curvula*, and as this diatom counts 89 thousand per inch it shows what this new lens can do with oblique light and a stop, the illuminant being an ordinary microscope paraffin lamp with a $\frac{1}{2}$ in. wick. With axial light, without any stop, the Brazilian *Lindheimeri* is dotted. On Möller's Typen-platte, with 400 forms, the *Nitzschia curvula* (there called the *N. sigmatella*) is very thin and difficult, and the lens fails to resolve it, but it easily resolves all the others on that line except the *Homoeocladia Martiniana*, which is more difficult than *A. pellucida*. It resolves the *N. crassinervis* on that plate quite easily, and it will just show the striae on the *Grammatophora oceanica*, which counts 88 thousand to the inch. This diatom is probably the *G. subtilissima*; anyhow, it is very much finer than the diatom of the same name on the Probe-platte.

The image given by this new lens of the Podura scale is very fine indeed. Undoubtedly in this new objective we have a lens of great beauty and power. An important question arises as to the influence this lens will have upon our battery of objectives.

In former times a 2 in., 1 in., a $\frac{1}{2}$ in., a $\frac{1}{4}$ in. and $\frac{1}{8}$ in. or $\frac{1}{16}$ in. represented a full battery, but now we may have a battery consisting of only a $\frac{2}{3}$ in. and an oil-immersion $\frac{1}{12}$ in. Here the gap is very wide, and the new lens will fill it very satisfactorily.

This lens will, to a certain extent, supersede the oil-immersion $\frac{1}{12}$ in. in medical schools and colleges. It is sufficiently powerful to do all that is wanted in practical study, but necessarily in research work a $\frac{1}{12}$ in. of wider aperture is required. For a student it will be especially valuable, for it has of course more working distance and a larger field than a $\frac{1}{12}$ in.

Another very important point is that, because of its great working distance, it does not pick up by capillary attraction an unfixed cover-glass. This is a source of great trouble when working with a $\frac{1}{12}$ in.

Zeiss supply a funnel for reducing the aperture of this objective, so that a dark ground may be obtained with an ordinary dry condenser and a stop. Of course with an oil-immersion condenser no funnel is required.

Henceforth, for research work, a perfect battery will consist of a 2 in., 1 in., $\frac{2}{3}$ in., $\frac{1}{3}$ in., this $\frac{1}{7}$ in., and a $\frac{1}{12}$ in. oil-immersion.

In the Navy, when Dreadnoughts were introduced, old-fashioned battleships were scrapped; so also in microscopical affairs those who are wise will scrap all their dry lenses of powers higher than $\frac{1}{3}$ in. or $\frac{1}{4}$ in.

One can foresee that the advent of this new lens means much, for just as oil-immersions have eclipsed water-immersions, so will this new lens supersede the wide-angled dry lens, which cannot compete with it in working distance, quality, field, or price.

It is to be hoped that Zeiss will issue an objective of this class for the long as well as for the short tube. The most notable feature in this new object glass is the near approach that has been made towards apochromatism without the use of fluorspar.

There is, however, another matter for your notice—viz. an entirely new way of using an object glass for diatom or other

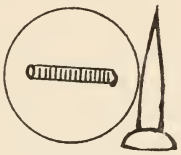

FIG. 1.

resolutions, a method, moreover, for which this new object glass is peculiarly suited. The method is so simple that it can be explained in a few words: (1) Place the diatom so that the striae to be resolved are vertical in the field. (2) Set up a critical image with the edge of the flame in focus and central to the field, and open the diaphragm to its full extent. (3) By means of the substage centring screws move the condenser so that the image of the flame lies just outside the field of a high-power eye-piece (fig. 1). If the striae are within the grip of the object glass they will be resolved.

It just amounts to this, that if one is working at diatoms with critical illumination and has need to resolve one, all that is necessary is to move the sideway adjusting screw of the substage and place the flame image just outside the field, and the thing is done in an instant, without any trouble with stops, slots, or other apparatus.

You will notice that the amount of the displacement of the condenser is very small (say twice the length of a *Navicula rhom-*

boides), so that this new kind of illumination must not be confused with that from a condenser considerably decentred, with the illuminant so placed that the light passes through the condenser obliquely, a form of illumination old and well known, or rather which used to be well known.

Although there is no difficulty in executing the necessary manipulation, the explanation of how the result is obtained is not so easy. First, no direct light from the flame enters the field, but it must be remembered that it is not a dark-ground image we are dealing with; for if it were high resolution would fail, as Mr. W. B. Stokes has pointed out. The field is not dark, neither is it light, but it is a sort of glow; from whence does this glow come? At first it was thought that it must arise from internal reflections in the front lens of the object glass, and that the lens was acting

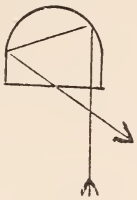

Fig. 2.

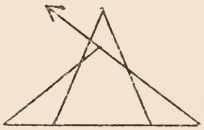

Fig. 3.

as its own lieberkühn, as in fig. 2. But further experiments have proved that this is not the case; no doubt some light may travel in that manner, but the amount that does so is quite small, and wholly insufficient for the purpose. The main body of this light is present owing to spherical aberration in the condenser, which gives rise to a very oblique beam, as in fig. 3. For this kind of illumination therefore a condenser with spherical aberration is to be preferred to one more aplanatic.

There can be no question about extraneous light from the illuminant having anything to do with it, for when a metal screen, with a slit the size of the edge of the flame, was placed close to the chimney, no difference in the effect was observed.

This kind of illumination will be of service, for it will enable an observer to obtain high resolution with a dry condenser, in an instant, without the troublesome manipulations usually necessary.

A NEW LOW-POWER CONDENSER.

By Edward M. Nelson, F.R.M.S.

(*Read April 28th*, 1914).

Fig. 4.

Some time ago I pointed out to the Club that microscopists were badly off for a low-power condenser, for, so far as I know, there is no such appliance to be had. Mr. Curties kindly exhibits to-night one he has made from my formula. This condenser is designed as a low-power illuminator, and not at all for the purpose of resolving fine diatom striae. With the top on, its focus is 1 inch, and with the top off 2 inches.* Both the lenses are achromatised, and it will be seen that it is particularly achromatic, as well as aplanatic; it will work from the lowest powers up to a $\frac{1}{4}$ inch.

The first object I examined with it was a *Navicula lyra*, with a Zeiss 12 mm. apochromat. I have been working with the microscope now upwards of forty years, and never before have I seen such a perfect image of this diatom. In general work, with the lower powers, the flat of the flame of a reading lamp is focused upon the object; this with the 2 inch condenser covers a large portion of the field, even of the lowest powers. It will give an excellent dark-ground for pond life, etc., up to say a $\frac{2}{3}$ inch objective. This condenser is to be named "Quekett," after that illustrious microscopist.

Speaking of dark backgrounds, there is a great defect in many condensers, viz. that the spot is not centred to the optic axis of the condenser, because the cell holding the stops is not placed accurately on the mount. This is a serious defect, because if the stop is not centred, the microscopist is forced to use a much larger

* This back lens of 2-inch focus when used by itself in a holder forms the best "verant" I have seen. It is very useful for the examination of large microscopical objects, as well as of flowers, engravings, coins, postage stamps, seals, etc.

stop than is necessary.* How often one sees a dimly lighted object, with a halo of bright fog, on one side of the field, owing to the use of an excentric stop larger than is necessary.

To remedy this defect, Mr. Curties shows a simple centring stop-holder made from my design. The stop consists of a disc with a hole in it which fits on a pin B; this I designed for my Jubilee microscope, which was made by Powell and exhibited at the Club in 1887.

Why microscopists will have their stops cut out of the sheet, a much more expensive plan than a disc fitting on a pin on a spider,

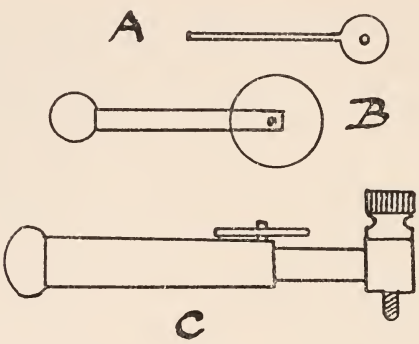

FIG. 4.

A, lever; B, flat tube with the stop on pin; C shows the flat tube placed on the lever, with screw for fixing the appliance beneath the iris-box.

I am unable to tell you. But to return, this pin is fixed to the end of a flat tube B, which slides on a flat bar A; this forms the centring adjustment right and left. The centring adjustment rectangular to this is in arc, by moving the arm C, which is pivoted below the iris box.

* If, for example, a centred stop of ·4-inch diameter is requisite, and supposing that the stop carrier is ·1 inch out of centre, then a stop of ·6 inch will be required to do the same work as the stop of ·4 inch. Now the area of a circle of ·6 inch diameter is more than double that of a circle ·4 inch diameter; this shows the great loss of light an excentric stop-holder causes.

BINOCULAR MICROSCOPES.

By Edward M. Nelson, F.R.M.S.

(*Read May 26th*, 1914.)

Fig. 5.

In recent years several binoculars have been introduced; none of them, however, can be called new. The first, the Greenough, by Zeiss * in 1897 was a twin microscope, a form of binocular invented by Père Cherubin d'Orléans nearly three hundred years ago. The second, by F. E. Ives in 1902,† is very similar to one designed by Wenham in 1866 as a counterblast to Powell's high-power binocular in which the whole beam is sent into each eye.‡ The third is a modification of the second by Messrs. Leitz,§ and the fourth, by Messrs. Beck, is very similar to that of Ives.

Before proceeding, let us enumerate the points gained by binocular vision. They are four in number and were stated by me in the *English Mechanic* || as follows:

1. Stereoscopism, or the power of appreciating solidity.
2. Increase of apparent magnifying power.
3. Increase of illumination.
4. Increase of colour perception.

The first binocular we have to deal with, viz. the Greenough twin microscope, became a practical form owing to the re-introduction of the Porro prism by C. D. Ahrens in 1888. Obviously, it can only be used with very low powers, but nevertheless I have had no reason to alter the favourable opinion I expressed for this form of binocular when it was first exhibited by Messrs. Zeiss. In this instrument all the above

* *Journ. R.M.S.*, 1897, pp. 599–600.

† *Ibid.*, 1903, p. 85, Fig. 3.

‡ I am indebted to Mr. Rousselet for kindly bringing the Ives binocular to my notice.

§ *Journ. R.M.S.*, 1914, p. 5.

|| 1911, Vol. 94, No. 2432.

four attributes of binocular vision are secured. In this microscope the left-hand view of the objective is sent into the left eye, and the right-hand view into the right eye; this, because of the erection of the image, gives an ortho-stereoscopic image. If the microscope had been of the ordinary inverting type the image would have been pseudo-stereoscopic. It was due to ignorance of this principle that several of the early binoculars were pseudo-stereoscopes. One of the most important points in this, as well as in all forms of binoculars, is that the images should be accurately superimposed. Several tests have been proposed; one was that an object should be placed upon the stage, so that it should just touch, say, the right edge of the field of the right-hand eye-piece. This eye-piece is then transferred to the left-hand tube, and if the object still touches the same portion of the field with the same eye-piece the adjustment was supposed to be correct. But this is no test at all, for it tells you nothing about the really important question, which is whether the discs of the fields are themselves superimposed.

The best test for a Greenough is to oscillate rapidly a strip of card half-inch wide before the fronts of the objectives. If the images shake, then they are not accurately superimposed, and the objectives require readjusting in their seats.

Leaving now the twin microscope, we will pass on to the other kind of binocular, which has only one objective. In the Wenham this important adjustment is performed by the alignment of the tubes, for the tilt of the prism has very little effect, but its edge must be carefully set at right angles to a line joining the centres of the eye-pieces.

The single objective binocular may be divided into two kinds, viz. those of the Wenham or Stephenson type, which split the beam at the back of the objective, and those of the Powell type, which pass the whole beam. All those of the Wenham type possess the first of the attributes enumerated above, viz. stereoscopic effect, for in an ordinary inverting microscope, at the left-hand eye-piece the Ramsden disc will be a miniature of a cross-section of the beam issuing from the right-hand half of the objective, and that at the right-hand eye-piece from the left-hand half of the objective, the inversion of the image necessitating a cross-over of the pencils, for if there were no

cross-over the image would be pseudo-stereoscopic. There is no cross-over in a Stephenson, but then it is an erecting microscope.

The binocular of the Powell type, which passes the whole pencil, does not possess the first attribute of stereoscopism : the image in both eyes being identically the same. No doubt, owing to the employment of both eyes and for physiological reasons, there may be more or less of a stereoscopic effect, but that is an entirely different thing from true stereoscopism. When, for example, the full moon is observed through a field-glass it appears as spherical as a cricket-ball, the images in each eye must be identical and no true stereoscopism can be present.

If half the Ramsden's disc above the eye-lens is stopped out by a diaphragm, so long as the cross-over is preserved, the image in an inverting microscope will be ortho-stereoscopic. This was mentioned by Wenham in 1854; and later, in 1882, Dr. Mercer pointed out that a diaphragm is not needed, but an ortho-stereoscopic effect may be obtained by making the inter-ocular distance less than the interpupillary, which causes the iris of the pupil of the eye to cut off the inner half of the Ramsden disc.

The disadvantage of a diaphragm above the eye-piece is that it occupies the same place as that in which the eye ought to be; and the disadvantage of Dr. Mercer's method is that the head and eyes must be kept absolutely steady, otherwise there will be a flickering of the image, which causes strain and distress to the eyes : the higher the power, the smaller the Ramsden disc and the greater will be the flickering and strain and fatigue to the eyes. For these causes ortho-stereoscopism in a binocular of the Powell type is of a different character from that of the Wenham or Stephenson type. In books dealing with this subject the Wenham super-eye-piece diaphragm and the Mercer narrow inter-ocular distance are treated as alternative plans, equal in efficiency to the Wenham divided objective method. Such, however, is not the case. It is only necessary to place two microscopes alongside each other, charged with similar objectives and powers, one having a Wenham divided objective and the other a Mercer narrowed inter-ocular distance, when an examination of the same object will at once dispel any theory

as to the equality of the results, the ortho-stereoscopism in the Wenham being superior to that in the other.

In the Wenham and Stephenson, ortho-stereoscopism is weak with objectives which have less than 20° of angular aperture (say $1\frac{1}{2}$ inch of ·17 N.A.), and the divided objective breaks down with high powers. A divided objective binocular may be said to be at its best with a $\frac{1}{2}$ inch; good with 1 inch, $\frac{2}{3}$, $\frac{4}{10}$, and $\frac{1}{3}$; fair with $\frac{1}{4}$; but failing with a $\frac{1}{5}$. Very small Wenham prisms have been made and mounted on a funnel and placed in the mounts of a $\frac{1}{12}$; the result being so indifferent that further experiments in that direction were abandoned.

The Wenham plan possesses a great advantage over all other kinds of stereoscopic binoculars, viz. that the straight tube is free from glasses, prisms, or other appliances likely to disturb the image. You will naturally ask, Why then was the Powell non-stereoscopic system introduced? The answer is that it was intended to come in where the Wenham left off, for Powell engraved on his Wenham prism, "For Low Powers," and on his own prism, "For High Powers." The reason why the high-power prism fell into disuse was on account of the poor definition that could be obtained with it. It had no clear tube like the Wenham, and it should be remembered that prisms and flat glass surfaces, owing to the manufacture of prism field-glasses, are now made with a precision and accuracy altogether unknown in 1865, when Powell made his.

Binoculars of the Wenham or divided lens type have the disadvantage of indifferent definition of objects placed vertically in the field. If, for example, that well-known test for medium powers, the hair of the *Polyxenus lagurus*, be placed vertically in the Wenham, with, say, a one-third objective, the definition will be fuzzy; but directly the hair is placed horizontally in the field, the image becomes sharp. In ordinary work with a Wenham, where an ortho-stereoscopic image is of primary importance, this defect is not noticed, and probably only a few microscopists are acquainted with it. But with the Powell type of binocular, this error does not exist. The image is the same in all azimuths. Now, in the Wenham high-power binocular, which was introduced in reply to Powell's, the beam was divided by two right-angled prisms with an air-space between them, the inclination of the surfaces being adjusted near to the critical

angle so that some of the light was passed while some was reflected. As this took place at both surfaces a double image was made in one tube, which, of course, was fatal to the design, and the binocular never came into use. Prof. Abbe's binocular eye-piece was made on a similar plan and failed for the same reason. Subsequently, however, a method was discovered for depositing a semi-translucent film of silver on glass, by which means a beam could be half reflected and half transmitted. This method was adopted by Ives, and the doubling of the image in the one tube was avoided. The Ives binocular resembled the Wenham, inasmuch as the prism could be withdrawn and the instrument used as a monocular. But it also differed from it, for in the Wenham the inter-ocular distance was adjusted by lengthening or shortening the draw-tubes, while in the Ives it was accomplished by a lateral displacement of the side tube in arc, the lower end of this tube being pivoted on a hinge. This was a good design, for it permitted the inter-ocular distance to be adjusted without disturbing the tube length. In 1860, when the Wenham was first introduced, low powers, with their double fronts, were very insensible to alteration of tube length, and as all powers higher than a $\frac{2}{3}$ had correction collars, any alteration of tube length was of no moment; this, however, no longer applies, because objectives now made with single fronts having over-corrected backs are very sensitive to tube length. So in designing a binocular for use with such objectives, particular attention must be given to tube-length adjustment.

Now, lately, Messrs. Leitz have brought out a new binocular of the Powell type; the arrangement of the prisms, which deflect the rays right and left, differs from the many kinds that have been invented for this purpose. The semi-translucent silver film method has been adopted by Messrs. Leitz in their new binocular, and an almost equally illuminated image is seen in each tube. By means of their very perfect system of working prisms they have secured a really sharp critical image in each tube. The tubes are parallel to one another, but the instrument cannot be used as a monocular, for neither body is in the optic axis of the objective. Messrs. Beck have also brought out a binocular microscope with the two Ives prisms joined in one. The bodies are converging, but as one body is in the optic axis of the instrument, it can be used as a monocular.

A great deal has been made of the difference between parallel and converging tubes. It has been urged that parallel tubes are conducive of eye strain and fatigue. Having now had a Leitz microscope in constant use for nearly three months, and having done prolonged work with it, no more eye-strain has been found with the parallel tubes than with a Wenham, and with both there is less fatigue than with a monocular.

To me the image plane in a microscope appears at so definite a distance that I seem able to hold a pencil in front of it, or behind it, or touching it. When using a binocular I simply look at the image in this plane, being quite as unconscious of either the parallelism or convergence of the eyes as if I were looking at various objects in the room, or on the table. During the course of these experiments several curious observations were made. Various persons were asked to examine the images in the Wenham and in the Leitz for the purpose of ascertaining their opinion as

FIG. 5.

to the relative amount of stereoscopic effect in each. Two persons having good normal vision saw no stereoscopic effect in either, the images in both instruments appearing quite flat; one of them could see no stereoscopic effect either in an ordinary stereoscope or in a field glass. Two others saw stereoscopism in the Wenham, but not in the Leitz with the Mercer method. With the same object and same power in both ($\frac{1}{2}$ inch and B eye-piece), most persons said that stereoscopism was stronger in the Wenham, owing probably to want of practice and experience with the Mercer method.

When the inter-ocular distance in the new binocular is kept of the same width as the inter-pupillary, the microscope is a non-stereoscopic binocular. The Mercer plan of reducing the inter-ocular distance is found to produce fatigue on account of the flickering of the image when the Ramsden disc is small.

Figure 5 shows the reason why eye strain and fatigue, which are present with the Mercer method, are absent with

the Wenham; the circles in W and M represent the pupil of the eye, the semi-circle in W is the Ramsden disc in a Wenham, and the portion of the circle in M is the Ramsden disc when the inter-ocular distance is less than the inter-pupillary in the Mercer method. It can at once be seen that a slight movement of the head will not affect the luminosity in W, but in M the head cannot be moved in the slightest degree without either increasing or diminishing the amount of the Ramsden disc cut off by the iris of the pupil; necessarily, therefore, if in one eye the Ramsden disc is enlarged it is cut off in the other eye, and *vice versa*, which is the cause of the flickering previously mentioned. A moment's consideration will show how this defect in the Mercer method may to a certain extent be minimised. Obviously the larger the Ramsden disc the less noticeable will be this defect. This, of course, points to the use of a low-power eye-piece with any given objective. The low-power eye-piece has an additional advantage—viz. that the rays emerge at a smaller angle than in the case of a deep eye-piece, and this permits the eye being held at a little distance from the proper eye-point, where the Ramsden disc is expanded. Hence the rule for stereoscopism with the new binocular is to make the inter-ocular distance somewhat less than the inter-pupillary, and not to use eye-pieces deeper than $1\frac{1}{2}$ inches, and to hold the eye a little way behind the eye-point.

There are two other sources of eye strain and fatigue common to all binoculars of whatever type; the first is non-coincidence of the superimposed fields. This by no means uncommon fault is due to carelessness in fitting and putting together; it is a source of great eye strain and fatigue, and the purchaser of a binocular microscope should be particular to see that the fields are precisely superimposed. The second is a difference of foci in the tubes. In the binoculars both of Messrs. Leitz and Beck provision is made for this by a focusing arrangement in one of the eye-tubes. In the Greenough it is accomplished by means of a focusing adjustment in one of the objectives. If, therefore, a microscope is provided with some such arrangement, the user need not be troubled about this point.

Passing on now to the second attribute of a binocular—viz. that of increased apparent magnifying power, it is found to be as obvious in a microscope as it is in a field glass. Its precise

amount is difficult to determine, nor is it known if it is the same for all persons. As I pointed out elsewhere, it is inaccurate to say that there is an increase of apparent magnification in a binocular; what really takes place is that in a monocular there is a diminution of apparent magnifying power, and that this diminution is non-existent in a binocular. If any one examines a lighthouse, a ship, or other object with a 2 or 3 power monocular telescope, the image appears no larger than when it is seen with the naked eye. The image, as any one will tell you, is brighter and clearer, but not larger. Directly the image seen in the telescope is superimposed on that seen with the other eye the magnification of the monocular is demonstrated, which generally causes surprise. Having given this subject considerable attention, I am of opinion that the true magnification is seen in a binocular, but that with a monocular, either telescope or microscope, this is reduced.

The third attribute—viz. illumination: It is doubtful if there is much gain in the Greenough type of binocular, as the amount gained by the use of both eyes is probably lost owing to the prisms, surface reflections, etc. Of course, with a single objective type of instrument there must be a loss. This is of no importance, for in a microscope one has usually more light than is needed.

The fourth attribute: Experiments have shown that colour tints are increased in a binocular; this is a distinct gain, for there is always much and often total loss of colour in microscopical observations.

There is another form of binocular which must be mentioned, viz. the binocular eye-piece. This was an early invention of Wenham; the next to take it up was Tolles, of Boston, U.S.A., who made a very good one by using prisms on the Nachet plan, dividing the beam by means of an isosceles prism. Tolles' binocular was well made, stood deep eye-pieces, and had the advantage that both tubes were similar; consequently the illumination and path of the rays was equal in each. The advantage this system possesses is that it permits of objective correction by draw tube. With other binoculars objective correction is not so easily accomplished.

The last form of binocular eye-piece was brought out by Professor Abbe. This, as we have seen above, was a failure.

There was another objection, viz. that the path of the rays was much longer in one tube than in the other, so that two different forms of eye-pieces had to be used. Very few were made, and it is probable that no more will be.

In conclusion let us examine the position of these new binoculars. From what has been said above they are clearly a class by themselves. It would be quite inaccurate to entertain the idea that these instruments are a new kind of stereoscopic binocular constructed to enter into competition with, and finally to supersede, the existing binoculars of the Wenham and Stephenson types ; for from what we have seen they only possess the first attribute, viz. stereoscopism in a limited manner. The word "limited" is used in default of a better expression. It does not mean that with the Mercer effect stereoscopism becomes less strong, for, on the contrary, with the Mercer effect hyper-stereoscopism is often present, and care should always be taken to guard against it. With the Mercer effect a cell, for example, which is, and which under a Wenham would look, like an ellipsoidal football will appear under a hyper-stereoscopic Mercer effect as if standing on end.

The centre of that beautiful diatom, plentiful on "Mud Cuxhaven" slides, viz. *Actinocyclus Ralfsii*, under hyper-stereoscopism appears at the bottom of a deep pit, the outer annulus being highly raised,* whereas we know that the structure is a kind of shallow saucer. The word "limited" is intended to apply to the stereoscopic condition that the Ramsden disc cannot be centred to the pupil. The Mercer plan also entails loss of light and of resolution of vertical striae. Messrs. Leitz provide their inter-ocular adjustment with a millimetre scale. The observer should carefully note the precise adjustment that will centre the Ramsden disc to his own eyes ; half a division on the scale (which represents 1 mm.) or even less ought to suffice for the Mercer effect. The test of coincidence of the inter-ocular with the inter-pupillary distance is that of maximum brightness. Luminosity quickly falls off with either increase or decrease of inter-ocular distance. With a little practice, one becomes so expert in judging the luminosity that a reference to the divided scale is seldom necessary.

* Seen best with transmitted light, a No. 4 objective and a 1 inch eye-piece.

You will then naturally ask, If these new binoculars are not stereoscopic, what is their use? Their use is confined to the employment of full Ramsden discs in each eye, that is for work with non-stereoscopic images. An enormous amount of microscopic work is done with images of that kind, and when prolonged work is undertaken with the new binocular great relief and comfort to the eyes will be secured. But to say, on the one hand, that one of these instruments when used for, say, the examination of pond life with a $\frac{1}{2}$ inch and the Mercer effect is going to supersede a Wenham, and on the other hand to state that by means of this new binocular delicate secondary structures on diatoms will be more easily seen than with a monocular, is to talk nonsense. At the upper limit they cannot compete with the monocular, and at the lowest limit they cannot compete with the Wenham; but in their own sphere they are extremely useful and form a very important addition to the modern improvements in Microscopy.

At any time with the new binocular the Mercer effect can be turned on to determine the relation of the various parts of an object; but it must be borne in mind that stereoscopism in a microscope with the higher powers is only partial, and whether it is present or not depends largely upon the nature of the object; for example, with a medium power, such as $\frac{1}{4}$ or a $\frac{1}{5}$, the rays of a Heliopelta will exhibit strong stereoscopism, but many other objects with the same power will show none. With a $\frac{1}{6}$ and a spread slide of *P. angulatum*, it is difficult to determine whether a valve is convex or concave side up. Stereoscopism in macroscopic vision differs from that in microscopic vision inasmuch as it is influenced greatly by the thickness of the object.

With macroscopic vision stereoscopism is seen equally well with either a book or a bookcase, but that is not so with microscopic vision. In that case stereoscopism would be present with our allegorical bookcase but not with the book. Low powers deal with thick, coarse objects, and therefore stereoscopism is present; but with the higher powers it is necessary to select suitable objects for the demonstration of the stereoscopic effect. For instance, bacteria dried on cover do not exhibit any more stereoscopism with the new binocular than with a monocular, for in a monocular they can be made to look like sausages; but

when bacilli in tissue are examined with the Leitz binocular, a $\frac{1}{12}$ and the Mercer method, a beautiful picture of them in perspective projection will be seen as well as of the cell nuclei which appear spherical as marbles.

It is a good plan when working with this new binocular to turn on the Mercer effect and when the form of the image has been mentally grasped to turn it either wholly or partly off, for when the stereoscopic form of an object has once been realised by the mind it can be retained, although the optical conditions which gave rise to it have been removed. Some will have noticed, when looking at parquetry representing cubes, that if the effect when first noticed is intaglio it is a matter of some difficulty to reverse this mental image so that the cubes shall appear to be in alto-rilievo.

I asked Messrs. Leitz to make me a couple of tubes to slide over their tubes, by which means tube-length adjustment can be accomplished. The tubes can be drawn up and down over the fixed tubes and the eye-pieces also can be partially drawn out, as the tubes are sprung both top and bottom. Without these tubes it was not possible to obtain a critical image with Messrs. Leitz' own objectives for the Continental short tube.

The great charm in these new binoculars consists in the sharpness of the image combined with ease and comfort of vision, hence the need for lens correction either by alteration of tube or by screw collar. The sharpness of image in my instrument at least is very little behind that of a monocular, for it requires a delicate test to perceive any difference at all, and often a pair of 18 compensating eye-pieces have been used with advantage.

With a $\frac{1}{4}$ inch objective and upwards, these new binoculars have the field all to themselves, as no other binocular for sharpness and crispness of image can for a moment compete with them. With low powers and $1\frac{1}{2}$ inch eye-pieces and a slight Mercer effect they give lovely images, but, as was hinted above, with the Mercer effect one must always be on one's guard against hyper-stereoscopism. Recently a shock was experienced on finding that a Radiolarian which appeared under the Mercer effect as round as an orange, when viewed on edge was shaped rather like a mince pie. Here the Wenham gave the truer image.

Latterly, even the Greenough, which is known to give beautiful images, has been suspected of hyper-stereoscopic tendencies.

I never expected to live to see a critical image of a Podura scale in a binocular, but that is now an accomplished fact, for I have seen a most beautiful picture of a Podura scale with the Leitz binocular and an apo 4 mm., and that, too, critical in all azimuths.

Dark-ground images are very suitable for the new binoculars because the objective is working at full cone, so there is a larger Ramsden disc than would be usually the case with transmitted light.

Messrs. Leitz sent with the microscope some of their new Orthoskop-Kellner eye-pieces, the performance of which is very satisfactory. I have had a cap, attachable to the eye-piece by a small screw, made to prevent the eye lens being smeared by contact with the eye-ball. This with a binocular happens frequently, so that a process of continual wiping of the eye-lens is necessary, which causes interruption and much interference with one's work.

NOTES ON THE CULTIVATION OF PLASMODIA OF *BADHAMIA UTRICULARIS*.

By A. E. Hilton.

(*Read May 26th*, 1914.)

Fig. 6.

A free-flowing mass of naked and almost undifferentiated protoplasm, such as we have in the plasmodium of *Badhamia utricularis*, suggests opportunities for biological experiments, with unusual promise of success. From living matter in so primitive a condition, it should be possible, one imagines, to gain a more intimate knowledge of the fundamental substance which is the basis of all physical life.

Systematic investigations, however, depend upon a constant supply of material, and a continuous supply of plasmodia is not easy to obtain. In natural surroundings, they are only to be found when conditions of temperature and moisture are suitable; and even then, in most districts, they are very scarce. Moreover, the removal of a plasmodium to a place suitable for studying it, generally results in the plasmodium shortly passing into the sporangial stage, or perishing from lack of proper nutriment. Either way, the immediate end is defeated.

In the Introduction to Mr. Lister's *Monograph of the Mycetozoa*, recently revised by his daughter, it is stated that "The plasmodium of *Badhamia utricularis* is one of the very few we are acquainted with that feed on living fungi," and that "it is capable of being cultivated without limit on *Stereum hirsutum* and allied species, and can be observed under the microscope to dissolve fungus hyphae as the hyaline border of a wave of the yellow plasmodium advances over them." In many places, however, an unfailing stock of the fungus mentioned is difficult to ensure; so that here, again, a difficulty arises.

Professor De Bary (1884), in his great work on the *Comparative Morphology and Biology of the Fungi, Mycetozoa and Bacteria*, mentions boiled cabbage leaves as having been used for the cultivation of Mycetozoa; but he does not name the species which were cultivated, and boiled cabbage leaves, if kept for any length of time, become too offensive for endurance.

In 1906, an account was published in Germany of experiments in the cultivation of plasmodia made by J. C. Constantineau; and these are alluded to both in Mr. Lister's *Monograph* and the Royal Microscopical Society's *Journal* for April 1907. In neither of these are details given, or any indication of the extent to which the experiments were successful. Possibly they were too technical to be of general use.

No apology, therefore, is needed for placing on record the result of experiments made during the last few months, which suggest a method of continuous cultivation of plasmodia of *Badhamia utricularis*, at once simple and practicable. Whether this method, with or without modification, is applicable to plasmodia of other species, I have not had an opportunity of determining. Other workers may perhaps take up the suggestion and carry the matter further.

In the first place, I have found that the growth of a plasmodium of *B. utricularis* can be stimulated by the occasional application of a mixture of ammonium phosphate * and cane sugar, half an ounce of the phosphate and the same weight of sugar being dissolved in a quart of water.

In the second place, I find that the plasmodium will feed and grow on bread kept moistened with water, especially if some of the mixture described be added to it from time to time.

The effect of the mixture seems to be both direct and indirect. It appears to impart greater vigour to the plasmodium, so increasing its feeding capacity; and it also benefits the plas-

* Since the above paper was read, Mr. James Grundy has informed me he has added calcium phosphate to the mixture with excellent results.

modium indirectly by promoting the growth of filamentous moulds, such as Aspergillus or Penicillium, which soon appear on fungus or bread, after the mixture has been applied to it. The hyphae of these moulds are dissolved and absorbed by the protoplasm as food.

In using the mixture discretion must be exercised, according to the condition of the plasmodium, as sometimes plain water is preferable; but the careful observer will find sufficient indications to guide him in this respect. No precise rules can be laid down, but the student will find that with these auxiliary helps he will be less dependent than heretofore on a supply of Stereum or similar fungus, although it may be advisable to use some of that at times, if convenient, as being the more natural food. Any fungus which becomes putrid must be removed, or it may poison the plasmodium; but the bread is not so liable to become injurious, and may remain a reservoir of protoplasm until, after a prolonged period, the plasmodium has eaten it all.

Note.—I have also been asked to describe, for the benefit of our readers, my method of exhibiting the reversing currents of streaming plasmodia, a description of which has been given in the Journal.* The very simple arrangement is shown in the diagram below.

Fig. 6.

A tube of this size is sufficient, and a ring of blotting-paper, with sclerotium upon it, is placed inside; the sclerotium being between the paper and the glass. A few drops of water are added, the cork is inserted, and the tube is then tilted and revolved until the water has soaked the paper and moistened the

* *Journ. Q.M.C.*, Vol. X., pp. 263–270, November 1908.

whole of the interior surface of the tube. A small hole is bored through the cork to admit air without allowing too much evaporation; or the cork may occasionally be removed. If necessary, a drop or two of water can be added now and then, to keep the air moist. Only plain water should be used. When the sclerotium revives, the plasmodium creeps on to the glass on either side of the ring of paper, and the reversing currents can then be seen by placing the tube on the stage of the microscope and throwing the light up through it from the mirror beneath. A 1 inch objective, focused on the veins of the spreading plasmodium, shows the streaming movements quite plainly. The sclerotium should be placed in the tube the day before the plasmodium is required for exhibition.

ON THE MINIMUM VISIBLE.

By A. A. C. Eliot Merlin, F.R.M.S.

(*Read October 27th*, 1914.)

I have read with great interest and profit our President's Address on "Organisms and Origins." The subject is one that must fascinate every microscopist, whatever his line of research may be. In the address a point was raised respecting the minimum visible, it being stated that "it seems impossible to obtain any precise information as to the size of the smallest particles that can be seen with the microscope."

Now, setting aside the ultra-microscope, as our knowledge is very exact and definite indeed on this subject, it may prove of interest to deal with the question at some length. As a matter of fact, when a particle properly illuminated is just visible under a given objective, if the aperture be cut down by means of an iris diaphragm placed above the back lens so that the particle just ceases to be visible, and the numerical aperture to which the objective has been thus reduced is measured, then the dimensions of the particle can be exactly ascertained from the antipoint table published by Mr. Nelson in the *Journal of the Royal Microscopical Society*. This antipoint table should prove invaluable when accurate and minute measurements are necessary, but little interest has been apparently evinced in the matter since micrometry of a high order is no longer practised, in England at least. Leaving this for the present, I venture to refer to and examine the claim made by Mr. Brown at a recent meeting of the Club that he had seen central "pores" on the surface of the frustules of certain diatoms; which he estimated at 1/200,000th of an inch in diameter. On reading Mr. Brown's "Notes on the Structure of Diatoms," * I examined a specimen of *Pleurosigma balticum*,

* *Journ. Q.M.C.*, Ser. 2, Vol. II. p. 317.

in realgar, under a very perfect recent 1/12th apochromat of N.A. 1·4, employed with a magnification of 4,200. Mr. Brown's central "pores" could be readily distinguished at a certain high focus on the outer layer of the valve. But in the "pores" so revealed I immediately recognised my old friends Dr. Royston-Pigott's "dark eidolic dots of interference." In thus frankly stating my conviction, I am sure that Mr. Brown, as a veteran observer, would wish me to pursue no other course. We are all liable to make mistakes in the interpretation of diatomic structure, and the only hope of progress lies in friendly criticism and the exchange of views. Although I consider Mr. Brown's central "pores" of *Pleurosigma balticum*, *Navicula serians* and *P. angulatum* to be clearly false ghosts, it is by no means unlikely that the outer layers of these diatoms may be perforated with fine secondary structure, like the forms with coarser primaries. Under the most critical conditions, with 1·4 N.A. and a magnification of 4,200, something of the kind has been seen both in *P. balticum* and *N. serians*. These appearances, however, are far more elusive and difficult than the eidolic central dots, and quite different in aspect and position. So far as my experience goes, capped diatomic primaries are always pierced by at least three or four secondaries when any such structure is observable. It may nevertheless be safely asserted that if the primaries of *P. angulatum* are thus capped and pierced, the secondaries must be as much beyond the grasp of our best lenses as are the eidolic dots of *A. pellucida*.

In order to show how similar are the observational conditions described by Dr. Royston-Pigott as necessary for the proper demonstration of eidolic dots to those specified by Mr. Brown concerning his central diatomic "pores," I must quote Dr. Royston-Pigott's remarks on the subject at some length. In "Microscopical Advances"* it is stated: "With regard to attenuated circles, nothing are more abundant in diatomic and scale markings. If a spherule be 1/60,000th of an inch, the black marginal ring is generally about one-fifth of this, or 1/300,000th thick, ornamented with a minute central black dot. The dot and its fellows are amongst the most interesting and surprising sights in minute microscopy. Few glasses will show them. That a

* *English Mechanic*, vol. xlviii. p. 209.

minute spherule should be capable of exhibiting the same *recherchés* phenomena as a delicate glass lens 1/30th focus solely from its refractions and chromatic aberrations, at first seems quite incredible." In another place * Dr. Royston-Pigott continues: "The existence of dark *eidolic dots of interference* is an important fact which now requires further elucidation. Darkness has resulted from excessive light. Wave neutralising wave, certain undulations killed each other. This is seen on a grand scale in the solar spectra formed by a small lens in the foci of a very fine microscope. Forty-eight dark rings have been counted developed by an extremely small solar beam. The feeble refractions occurring in a diatomic convexity cannot develop a very numerous retinue of rings; but sufficient diatomic lenses have been accumulated for the purpose indicated. To exhibit successfully a series of *eidolic dots of interference* demands very careful illumination and a very fine objective. Their size varies with the nature and diameter of the refracting spherule. The 1/8th water lens of Powell and Lealand seems to excel all my others in detecting them in different focal planes. Six have been in order thus seen, but in small spherules such as those of *P. angulatum* many dots are too faint for recognition. My experience of scale molecules has convinced me they also are wonderfully transparent, display black marginal test rings, and often one eidolic dot." . . . "These dots are well developed by large beading of diatoms from 1/9,000th to 1/14,000th of an inch in diameter. Extremely large spherical beads are seen in *Cresswellia superba* and in *Cestodiscus superbus* (beads 1/12,500th); *E. costatus* and *Coscinodiscus radiatus* are also fine examples. To exhibit successfully all the eidolic dots of interference in successive focal planes demands very excellent glasses, careful precautions, and, above all, well-separated diatomic beads. They may be caught above very small diatomic and scale beading. Remarkably good eyesight has distinguished them above the bosses of *P. angulatum* and occasionally I have detected two sets of dots when one stratum of beading lies just below another. In general, except in strongly pronounced diatomic bosses, the observer may rest satisfied with finding the primary eidolic dot, No. 1, fig. 1 in the diagram.† A better glass

* *English Mechanic*, vol. xlix. p. 315.

† A diagram showing a series of eight gradually diminishing dots is annexed to the original paper.

may enable him to detect Nos. 2 and 3 by daylight. Lamplight, unless its yellow tint be subdued with a blue chimney and other blue glasses, extinguishes the dot by the flame image produced by the diatomic lens. It may be recovered, however, in front of it by careful manipulation." . . . "Dr. Van Heurck obligingly photographed with the new apochromatic glass the eidolic dot shown by the beading of *P. angulatum*."

Dr. Royston-Pigott estimates the dots in *P. angulatum* to be attenuated to 1/250,000th of an inch and considers that extremely minute dots, about 1/300,000th, are not only found amongst diatoms, but reveal themselves in the transparent beadings of moth-scales, and adds, "but there are many forms of these dots." It is also remarked that "exquisitely small and black dots can often be seen in focal planes elevated slightly above diatomic beads by using a black central stop below the condenser. It requires very grand glasses to display these elegant results." It is needless to point out that the late Dr. Royston-Pigott was an upholder of the now abandoned view that the perforations of diatoms were solid silex beads or bosses. The foregoing sufficiently proves that the central eidolic dots or "pores" of diatoms were well known twenty-six years ago, but those specially interested in the subject should read the papers referred to.

Setting aside all such diffraction phenomena, or false ghosts, probably the most delicate, true diatomic structures just within the grasp of our finest modern objectives of large aperture are the thin perforated "veils" to be detected on certain diatoms. Of these perhaps one of the best examples is *Triceratium americanum*, var., Oamaru, mounted in styrax by Möller. It is a difficult structure with axial screen illumination, but there can be little or no doubt that the appearances observable represent real perforations in a thin outer plate. In this diatom there is no complicated structure to bewilder the observer and manufacture false ghosts. It is, however, extremely improbable that the minute perforations of the *Triceratium americanum*, difficult as they are, represent anything smaller than the 1/100,000th of an inch, and being subject to the limitations of the laws of diffraction, like all periodic structures, are consequently of little help as an example of the minimum visible under more favourable conditions.

In biological investigations it is frequently required to view widely scattered living particles, or germs, of various sizes down to the most minute dot that can just be detected. When any such particle is under observation nothing is easier than to measure its dimensions accurately by the antipoint method. There is in my cabinet a section of fluor spar, given to me by Mr. Traviss, which contains numerous liquid-filled cavities of various sizes. In each cavity there is a rapidly moving bubble. Some of these bubbles, under a 1/12th apochromat of 1·4 N.A., appear as mere trembling specks only just visible and within the grip of the objective, and there are probably others too minute to be seen at all. Selecting a bubble just visible under such conditions when illuminated with a large axial cone and Gifford screen, if we wish to ascertain its diameter we have only to refer to Mr. Nelson's papers, "A Micrometric Correction for Minute Objects,"* and "The Influence of the Antipoint on the Microscopic Image shown graphically."† These papers contain all the necessary explanations and data, and we find from the amended table in the latter paper that with a working aperture of 1·4 and screen the minimum particle visible must have a diameter of 0·00000265 (1/377,358th) in., or 0·0673 μ: the photographic limit being with similar aperture 0·00000209 (1/478,469th) in., or 0·5031 μ.

Thus we can measure accurately the diameter of the smallest particle or bubble visible with a given aperture. The accuracy of the result depends on knowing exactly the N.A. employed at extinction point, and this must in each case be found with an accurate apertometer. It is advisable that the working aperture should nearly equal the N.A. of the objective at the extinction point, but it need not necessarily be quite full cone. When the critical point is reached a very slight decrease of N.A. makes all the difference between easy visibility and invisibility. Mr. Nelson's first table "was computed by the formula

$$\frac{1}{5{\cdot}4686\lambda \text{ W.A.}}$$

The numerical coefficient was determined from data found by the

* *Journ. R.M.S.*, 1903, pp. 579–82.

† *Ibid.*, 1904, pp. 269–71. See also "On the Measurement of Very Minute Microscopical Objects" (*Journ. R.M.S.*, 1909, pp. 549–50).

extinction of the image of a minute point by reducing the W.A. to 0·165. The size of the point was measured by a wide-angled oil-immersion, and a W.A. of 0·9, and was found to be apparently 1/50,050th inch. From this we have

$$6{\cdot}6961\lambda{\cdot}165 = 50{,}050.$$

And

$$\frac{1}{6{\cdot}6961\lambda{\cdot}9} = 0{\cdot}000003663.$$

Employing this as a provisional correction, we find the size of the point to be 1/42,396th in. Again, using this measurement, we obtain a new numerical coefficient, viz. 5·6587, and finally find the size of the point 1/40,875th in., and the coefficient 5·4686 as stated above. In this calculation λ is the reciprocal of the wave-length, or the number of waves per inch, given at the head of each column in the table." In Mr. Nelson's subsequent paper, "The Influence of the Antipoint on the Microscopical Image shown graphically," the data will be found for the slightly amended table given therein.

Shortly after the publication of Mr. Nelson's papers on this interesting subject, Dr. Coles kindly sent me a well-stained balsamed slide of the putrefactive microbe *B. termo*. On this I was able to find a distinctly flagellated specimen suitable for measurement by the extinction method. The flagellum could be plainly seen with an apochromatic 1/6th of 0·98 N.A. used with a full cone and screen, and it became invisible when the N.A. was gradually cut down to 0·42 by means of an iris diaphragm over the top lens of the objective, thus making the diameter of the flagellum 0·00000891 (1/112,209th) in., or 0·226 μ.

Afterwards a balsamed-stained, flagellated specimen of the tubercle bacillus was found. This was more difficult to see, and the flagellum was thought to be much finer than that of the *B. termo*. A 1/8th apochromat of 1·4 N.A. was employed to measure this. When the N.A. was cut down to the vanishing point and tested with the Abbe apertometer, it was found to be exactly 0·42, thus making the diameter of the tubercle bacillus flagellum precisely equal to that of the *B. termo*. It may here be mentioned that the existence of the tubercle bacillus flagellum, discovered by Mr. Nelson, has been denied. It has, however,

been observed by many microscopists, including myself, and has been beautifully photographed by Mr. Nelson.*

Now the flagellum of *B. termo* was most carefully measured by the late Dr. Dallinger, and his results were embodied in a paper entitled "On the Measurement of the Diameter of the Flagella of *Bacterium termo*: a Contribution to the Question of the 'Ultimate Limit of Vision' with our Present Lenses." † Two hundred measurements were made by means of a fine pencil mark made over half or two-thirds, not over the whole, of the camera-lucida image of the flagellum. The labour entailed may be judged from Dr. Dallinger's statement: "Now I made fifty separate drawings and measurements with each of the four lenses, the same conditions being observed in each case. The results expressed in decimal fractions are as follows, viz.:

"1. The mean value of fifty measurements made with the 1/12th in. objective gives for the diameter of the flagellum 0·00000489208.

"2. The mean value of fifty measurements made with the 1/16th in. objective gives 0·00000488673.

"3. The mean value of fifty measurements made with the 1/25th in. objective gives 0·00000488024.

"4. The mean value of fifty measurements made with the 1/35th in. objective gives 0·00000488200.

"We thus obtain a mean from the whole four sets of measurements, which gives for the value of the diameter of the flagellum of *B. termo* 0·00000488526, which, expressed in vulgar fractions, is equivalent to 1/204700th of an inch nearly; that is to say, within a wholly inappreciable quantity."

These classical measurements of the diameter of the *B. termo* flagellum are of the greatest importance, for by their means the accuracy of the extinction method is demonstrated, which in turn serves to confirm the exactness of the late Dr. Dallinger's results. Assuming that a W.A. of 0·8 was employed, the necessary anti-point correction by Mr. Nelson's amended table is 0·00000513th in., which, added to Dr. Dallinger's mean, makes 0·00001001 (1/99,900th) in. for the true diameter of the flagellum, as against 0·00000891

* *Journ. Q.M.C.*, Ser. 2, Vol. XI. Pl. 22.
† *Ibid.*, 1878, pp. 169–75.

(1/112,200th) in., the diameter obtained by me from Dr. Coles's specimen by extinction measurement. The latter method is certainly not second to Dr. Dallinger's in exactness, whileit is undoubtedly less laborious. Through no fault of his own, Dr. Dallinger's uncorrected figures put the diameter of the flagellum at half its true dimensions.

REMARKS ON TWO SPECIES OF AFRICAN VOLVOX.

By Charles F. Rousselet, F.R.M.S.

(*Read October 27th*, 1914.)

The slides of two species of African Volvox which I am exhibiting to-night have a history of unusual interest.

It will be remembered that at the meeting of this Club on October 25th, 1910, a paper was read by Prof. G. S. West of Birmingham University, in which two new species of Volvox from Africa were described.

One of these, *Volvox africanus*, of small size and oblong in shape, was found in a Plancton collection made in July 1907 by Mr. R. T. Leiper, of the Egyptian Government Survey, near the northern shores of the Albert Nyanza. I received a very small quantity of this collection for the purpose of determining the Rotifera it contained, and found these pretty oval colonies of Volvox, as did also Prof. West, who had received a similar sample, in order to name the various fresh-water algae contained therein.

The other species is of very much larger size (as much as 1/20th inch in diam.), of spherical shape and densely crowded with cells on its surface (estimated at 50,000 cells in one of the larger Colonies), was found by myself on the occasion of the visit of the British Association to South Africa in September 1905 at Gwaai Station in Rhodesia, about half-way between Bulawayo and the Victoria Falls of the Zambesi; the train stopped for half an hour at this station by the side of a shallow pool formed by the Gwaai River, and as usual I jumped out of the train with my collecting-net and bottle and secured a dip from the pool. As the train went on I examined the contents of my bottle, and besides various Rotifera I noticed some large colonies of Volvox. The whole collection was put up in formalin, and eventually the specimens of Volvox were handed over to Prof. West for description, which was done in our Journal in November 1910.*

Of both these African Species of Volvox vegetative colonies only had been found, and Prof. West expressed his regret that the sexual colonies in various stages were not represented, so that his description was necessarily incomplete.

This closed the first stage of the story.

In May 1912 Dr. A. W. Jakubski published in the *Zoologischer Anzeiger* a paper on Rotifera collected by him in the Ussangu Desert in German East Africa, in which several new species of Distyla were figured and described. At that time Mr. James Murray was writing papers on the Rotifera of Australasia and South America and in particular was studying the family of the

* *Journ. Q.M.C.*, Ser. 2, Vol. XI., p. 99–104.

Cathypnidae, and we considered it very desirable to obtain, if possible, specimens of the new species described. So after I had ascertained that the author was working at the Zoological Institute at Lemberg University I wrote to Dr. Jakubski asking him to be good enough to send me a little of the material containing the species of Rotifera. Some time in the spring of 1913 the Doctor very kindly sent a few slides and also about eighteen tubes of Plancton material collected in German East Africa. By this time Mr. James Murray had left England on his way to the disastrous North Canadian Arctic Expedition, from which he has not returned, and being myself much occupied with other work, I delayed the examination of this material until the spring of the present year, when I received a polite reminder from the sender asking for the return of his tubes as soon as convenient. This request obliged me to look over the contents of the tubes without further delay, which was done in May and June last.

In his paper the author states that in deserts of German East Africa pools and ponds are rare and can only be found after heavy rainfalls, and are then shallow and last a very few weeks only, but often develop a considerable amount of Plancton organisms.

In two of the tubes, amongst various Rotifera, I was surprised and fortunate to come across numerous colonies of Volvox which I at once recognised as the same two species from Africa described by Prof. West four years previously. Moreover both species were present in various sexual stages with androgonidia and oospores, the male and female colonies, as well as the vegetative colonies.* The ripe star-shaped oospores of the large *Volvox Rousseleti* in particular are very fine and remarkable, and these specimens will now enable Prof. West to describe the complete life-history of both these African species, which appear to be widely distributed in that continent, though not as yet known from any other part of the world.

After completing my examination of the material I returned all the tubes to Dr. Jakubski at Lemberg in Galicia early in July, but have not heard whether they reached him. The tragedy of the situation is that at the end of the same month war was declared and Lemberg (Lwòw) was one of the first towns of importance taken and occupied by the Russian army, and it is at present impossible to ascertain what has become of either my correspondent or his collection of specimens.

You will agree that it was a piece of extraordinary and remarkable good luck that these collections came into my hands and at this particular time.

* Slides were exhibited by Mr. Rousselet showing the various sexual stages.

REPORT ON THE CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES (BRITISH ASSOCIATION) HELD AT HAVRE, 1914, BY INVITATION OF THE ASSOCIATION FRANÇAISE POUR L'AVANCEMENT DES SCIENCES.

(*Read October 27th*, 1914.)

To the President and Council of the Quekett Microscopical Club, London.

As your Delegate I attended the Havre Congress of the French Association, which began on Monday, July 27th. The Opening Meeting was held in the Grand Theatre, where Monsieur Armand Gautier, the President, welcomed the members and delivered an address. On behalf of the English members Sir William Ramsay addressed the meeting in French. In the evening there was a reception by the Mayor and Corporation in the Town Hall. On the Tuesday I attended a Conference of the Delegates of Corresponding Societies in the Town Hall, when Sir E. Brabrook read a discourse on behalf of the Chairman, Sir H. G. Fordham, who was absent, "On the History of British Association Conferences of the Delegates," of which it appears Mr. John Hopkinson was the founder. Mr. Hopkinson read a paper on "Local Natural History Societies and their Publications," in which he advocates certain rules in the publication of Transactions which would render them more easily capable of being referred to and quoted by inquirers or the bibliographer, and at the same time save expense in making reprints for distribution by the authors.

Sectional Meetings took place on the Tuesday and Wednesday, although clouds were then gathering on the political horizon, and some presidents of Sections did not appear. On the Thursday, July 30th, the Congress went on an excursion by train and boat up the River Seine as far as Rouen, visiting many historical places of interest and some famous old and ruined cathedrals and ancient Roman settlements, such as Lillebonne, Caudebec, Jumièges, La Bouille, on the way.

On the following day, Friday, more meetings of Sections were

held, but were very poorly attended, as the political outlook was more and more threatening and many members were called away and left hurriedly.

On Saturday, August 1st, most presidents and secretaries of Sections had gone and only a very few meetings took place. On that morning at the Zoological Section I read a short paper in French on "Pedalion or Pedalia, a Question of Nomenclature in the Class Rotifera." About midday a Government announcement or "Decret" was placarded at the Town Hall and at Post Offices ordering a general mobilisation of the French Army, to commence at midnight, when the Congress broke up.

I left Havre the same night by steamer for Southampton, where I arrived on Sunday morning, about three hours late, the boat having been held up several times in the Channel by torpedo-boats. Thus ended a most tragic meeting of a Congress for the Advancement of Science.

(Signed) CHARLES F. ROUSSELET.

PEDALION OU PEDALIA; UNE QUESTION DE NOMENCLATURE DANS LA CLASSE DES ROTIFÈRES.

Par Charles F. Rousselet.

[*Paper read by the author as the Quekett Club's Delegate to the Conference of Delegates of Corresponding Societies of the British Association held at Havre by invitation of the Association Française pour l'Avancement des Sciences. Section de Zoologie, Séance du* 1er *Août* 1914.]

Au 6me Congrès de l'Association Française pour l'Avancement des Sciences tenu au Havre en 1877 M. Jules Barrois présenta un mémoire portant le titre: "Sur l'anatomie et le développement du *Pedalia mira*." (Séance de la Section de Zoologie du 30 Août 1877.)

Or en 1871 le Dr. C. T. Hudson avait découvert dans une mare d'eau douce à Clifton près de Bristol un Rotifère extraordinaire, ayant six membres arthropodiques, l'un sur la face ventrale, un second sur la dorsale, et deux de chaque côté du corps, au moyen desquels l'animal peut nager et avance dans l'eau par petits sauts, semblables aux mouvements des larves des crustacés Cyclops. Hudson nomma l'animal *Pedalion mirum*.

En examinant ces jours le volume des Comptes rendus du Congrès de 1877 j'y trouve à la page 661 un Extrait de la communication de Barrois portant le titre ci-dessus. On voit que le nom de *Pedalion* a été changé en celui de *Pedalia*. En lisant plus loin on y trouve les phrases suivantes:

"M. J. Barrois a été conduit par ses études sur les Bryozoaires à considérer la forme primitive de ces animaux comme comparable à l'état adulte des Rotifères. Pour élucider cette question M. Barrois a entrepris au laboratoire de Wimereux l'étude de l'embryogénie du genre Pedalion si intéressant par la diversité de ses organes appendiculaires et dont une espèce est assez commune à Wimereux. Ce Pedalion est une espèce marine. Il présente, outre les deux épaulettes ciliées, six lambeaux d'épithélium ciliaire qui forment par leur réunion une couronne presque complète; les organes appendiculaires de la face orale sont au nombre de six: quatre pointes chitineuses et deux boutons à cils raides; les points oculiformes sont au nombre de trois, dont deux appartiennent à la face orale."

On voit que le nom de Pedalion est mentionné deux fois dans cet extrait, tandis que celui de Pedalia n'y est pas nommé du tout, ni y trouve-t-on une raison quelconque pour ce changement de nom, qui se trouve uniquement dans le titre du mémoire de M. Barrois.

La question donc s'impose : qui a écrit ce titre ? est-ce M. Barrois, ou le rédacteur des Comptes rendus du Congrès ? J'ignore si le mémoire de Barrois a été publié en entier quelque part, et je serai bien content d'en être informé. La *Revue Scientifique* du temps (No. 13, du 29. Sept. 1877) a publié le même extrait, sans le titre cependant, et par conséquent le mot Pedalia n'y est pas mentionné, mais seulement celui de Pedalion à deux fois.

Il y a autre chose encore : par la description que donne Barrois il ressort bien clairement que son Rotifère n'était pas Pedalion, qui ne vit pas dans la mer, n'a que deux yeux, n'a pas d'épaulettes ciliées, ni de couronne ciliée en six lambeaux, ni six organes appendiculaires sur la face orale. Toute cette description s'applique parfaitement à une espèce marine du genre Synchaeta (probablement *S. triophthalma* Lauterborn, qui porte ses œufs suspendus à la pointe de son pied en nageant), mais pas du tout au *Pedalion mirum* de Hudson, qu'on rencontre un peu partout en été dans des mares d'eau douce.

Il existe deux autres espèces de Pedalion (*P. fennicum* Levander et *P. oxyure* Sernow) qui se trouvent tous deux dans les eaux saumâtres en Asie, en Egypte, en Amérique et en Australie, mais aucune espèce n'a encore été découverte en mer.

Par suite de l'application des règles internationales de nomenclature le nom du genre Pedalion doit tomber, ce nom ayant été appliqué précédemment à un poisson (Swainson 1832), et à un mollusque (Solier 1847).

Il est donc utile et nécessaire de rechercher qui a le premier employé le nom de Pedalia, et j'invite les membres de la Section de Zoologie de bien vouloir me communiquer le mémoire complet de M. Jules Barrois s'il existe, ou toute autre information qui pourrait élucider cette question.

Je ne parle pas de l'Hexarthra de Schmarda, qui pourrait très bien être une espèce encore plus ancienne de Pedalion ; c'est une autre question que j'espère pouvoir résoudre sous peu, après m'avoir procuré des pêches dans le même marais d'eau saumâtre à El Kab en Egypte où Schmarda a découvert son Hexarthra en Mars 1853.

Il résulte de cet exposé que M. Jules Barrois (ou peut-être quelqu'autre personne) a non seulement changé le nom de Pedalion en celui de Pedalia, mais encore l'a appliqué à un Synchaeta.

THE LIBRARY.

BOOKS PURCHASED SINCE JANUARY 1914.

Optical Convention. Vol. II. 1912.

Sylloge Algarum Omnium. Vol. II. Sect. II. J. Bapt. De Toni, 1892.

Bacteriological Examination of Food and Water. Wm. G. Savage, B.Sc., M.D., D.P.H., 1914.

BOOKS AND PHOTOGRAPHS PRESENTED SINCE JANUARY 1914.

Revue Suisse de Zoologie à propos de Rotifères. Vol. XXII. No. 1. January 1914. E. Penard.

Presented by the Author.

Sylloge Algarum Omnium. Vol. II. Sect. I. Raphideae. J. Bapt. De Toni.

Presented by the Author.

My Sayings and Doings. Rev. Wm. Quekett.

Presented by G. W. Watt.

Cothurindés Muscicoles. E. Penard.

Presented by the Author.

Sur quelques Teulaculifères Muscicoles. E. Penard.

Un curieux Infusoire, *Legendrea bellerophon*. E. Penard.

Presented by the Author.

Eighty Photographs of Drawings of Rotifera. By F. R. Dixon-Nuttall.

Presented by F. R. Dixon-Nuttall.

Eighty Photographs of Rotifera.

Presented by J. B. Groom.

Royal Society of Victoria: Further Notes on Australian Hydroids. Part II. W. M. Bale, F.R.M.S.

Presented by the Author.

Odonaten-Studien. C. Wesenberg-Lund.

Presented by the Author.

Wohnungen und Gehäusebau der Süsswasserinsekten. C. Wesenberg-Lund.

Presented by the Author.

Fortpflanzungsverhältnisse Paarung und Eiablage der Süsswasserinsekten. C. Wesenberg-Lund.

Presented by the Author.

Commonwealth of Australia, Department of Trade and Customs: Fisheries. Biological Results of Fishing Experiments carried on by T.I.S. *Endeavour*. 1909–14.

Report on the Hydroida Collected in the Great Australian Bight and other Localities. W. M. Bale, F.R.M.S.

Presented by the Author.

The Journal of Micrology. Parts I.–IV.

Presented by H. Edwards.

For Sale—50 copies—reprints of Paper "Lagenae of the South-West Pacific Ocean," by Henry Sidebottom. Two Parts. Price 2*s*. 6*d*. Application should be made to the Librarian.

THE CLUB CABINET.

The following Slides have been added to the Cabinet since October 1912:

Protozoa.

Presented by G. T. Harris.

K.A. 106. *Actinosphaerium Eichorni* (binary fission).

Infusoria.

Presented by J. C. Kaufmann.

K.A. 102. *Euglena* sp.

Presented by J. Burton.

107. *Euglena viridis.*

Presented by G. T. Harris.

103. *Ephelota* sp. (stained to show nucleus).
104. *Ephelota* sp.
105. *Noctiluca miliaris.*

Hydrozoa.

Presented by G. T. Harris.

(s = stained.)

M.A. 4. *Aglaophenia pluma*, s.
50. *Aglaophenia pluma* (gonophores).
51. *Bougainvillia muscus.*
14. *Calycella syringa.*
23. *Campanularia flexuosa*, s.
52. *Campanularia flexuosa.*
53. *Campanularia neglecta.*
54. *Clava carnea.*

M.A. 55. *Clava carnea*, s.
56. *Clava multicornis*, s.
57. *Clava squamata*, s
17. *Clytia Johnstoni*, s.
58. *Clytia Johnstoni.*
91. *Clytia Johnstoni* (medusa).
19. *Cordylophora lacustris*, s.
59. *Cordylophora lacustris* (with compound bud), s.
8. *Coryne pusilla*, s.
60. *Coryne vaginata* (gonophores), s.
61. *Coryne vaginata* (*with* epiphytal *Licmophora flabellata*).
62. *Coryne vaginata*, s.
63. *Eudendrium insigne.*
64. *Eudendrium insigne* (*with* Ephelota : Infusorian).
65. *Gonothyrea Lovéni.*
66. *Halecium Beanii.*
67. *Hydra fusca.*
68. *Hydra viridis* (ovary and testes), s.
69. *Hydra vulgaris*, s.
92. *Lizzia Blondini* (medusa).
93. *Lucernaria fascicularis* (medusa).
70. *Obelia dichotoma*, s.
71. *Obelia dichotoma.*
72. *Obelia geniculata*, s.
73. *Obelia geniculata.*
74. *Perigonimus sessilis.*
75. *Plumularia echinulata.*
76. *Plumularia echinulata.*
77. *Plumularia echinulata*, s.
78. *Plumularia echinulata*, s.
79. *Plumularia halecoides*, s.
80. *Plumularia halecoides.*
81. *Plumularia pinnata.*
82. *Plumularia setacea.*
83. *Plumularia setacea.*
84. *Plumularia setacea* (metatophores).
85. *Plumularia similis*, s.
86. *Plumularia similis.*
87. *Podocoryne areolata*, s.

M.A. 28. *Sertularia filicula.*
88. *Sertularia pumila*, s.
89. *Sertularia pumila.*
90. *Sertularia pumila.*

Echinodermata.

Presented by J. Burton.

N. 19. Plates of *Taeniogyrus Allani.*

Rotifera.

Presented by J. C. Kaufmann.

Rot. 246. *Lacinularia elliptica.*

Turbellaria.

Presented by H. Whitehead.

Series 20: *with descriptive notes and diagrams.*

Microstomum lineare.
Phaenocora (*Derostomum*) *punctatum.*
Dalyellia viridis.
Dalyellia diadema.
Gyratrix hermaphroditus.
Dendrocoelum lacteum.
Planaria alpina.
Planaria alpina: tr. and long. secs.
Planaria gonocephala.
Polycelis nigra.
Polycelis nigra: tr. sec.
Polycelis cornuta.

N.B. 35. Tr. sec. (serial) of a Planarian.

Insecta.

Presented by T. A. O'Donohoe.

R. 402. Scales of *Templetonia crystallina.*
403. Scales of *Seira Buskii.*

Presented by F. H. N. C. Kemp.

399. *Naucoris cimicoides* (adult).

Polyzoa.

Presented by G. T. Harris.

M.B. 33. *Aetea anguina.*
84. *Bowerbankia imbricata.*
85. *Pedicellina cernua.*
86. *Pedicellina cernua*, var. *gracilis.*

Physiological Histology.

Purchased. (With descriptive, illustrated text.)

Series 10. *The Skin.*

Human scalp, with hair : long. and tr. secs.
Human scalp, with hair : long. sec., injected.
Human skin, with perspiration glands : long. sec.
Human skin, stages of development of perspiration glands : long. sec.
Human skin, with blood vessels injected : long. sec.
Skin of Dog, with elastic fibres : long. sec.
Tactile hairs of Ox, with blood sinus : tr. sec.
Human hair, stages of development : long. sec.
Human nail : long. sec.

Series 11. *Muscle, bone, etc.*

Human embryo, finger and arm : long. secs.
Muscle of Ring Snake, with motor nerve plates.
Muscle of Dog : tr. sec. and long. sec., injected.
Tendon of Ox : tr. sec.
Cervical ligament of Ox : sec.
Bone of Ox : long. sec.
Cranial bone of Dog : sec.
Joint of Rabbit : median sec.

Series 12. *Central nervous system.*

Spinal cord and ganglion of Cat : tr. sec.
Spinal cord of Cat (Golgi preparation : cell impregnation).
Spinal cord of Dog : tr. sec.
Cerebral cortex of Cat (Golgi preparation : cell impregnation).

Cerebellum of Cat (fibre impregnation).
Cerebrum of Man (fibre impregnation).
Pineal gland of Ox: tr. sec.
Pituitary gland of Ox: tr. sec.
Embryonic spinal cord of Fowl.
Embryo of Rabbit: tr. sec.

Series 13. *Reproductive organs.*

Penis of Bull: tr. sec.
Glandula vesicularis of Bull: sec.
Spermatozoa of Bull.
Testis of Mouse: tr. sec.
Umbilical cord of Child: tr. sec.
Gravid uterus of Pig: tr. sec.
Oviduct and ovary of Dog: tr. secs.
Ovary of new-born Kitten: tr. sec.
Mammary gland of Cow: tr. sec.

Series 14. *Respiratory and urinary organs.*

Lung of Cat: injected.
Lung of Cat (elastic fibres).
Lung of Dog (cell pigmentation).
Trachea of Cat: tr. sec.
Kidney of Rabbit: injected.
Kidney of Mouse: tr. sec.
Bladder of Ox: tr. sec.
Supra-renal capsule of Ox: tr. sec.
Embryonic okenian body of Pig: tr. sec.
Thyroid gland of Man.

Series 15. *The Eye.*

Cornea of Ox (gold impregnation).
Choroid of Ox, showing pigment cells.
Retina of Ox.
Optic nerve of Ox: med. sec.
Eyelid of Calf: med. sec.
Lachrymal gland of Ox.
Glands of nictitating membrane of Rabbit.

Anterior half eye of Ox, without lens : hor. sec.
Eye of embryo Chick : med. sec.
Eye of embryo Pig : med. sec.

Series 16. *Organs of hearing, smell and touch.*

Auditory organ of Cat (sensory hairs of ampullae).
Auditory organ of Cat, membrana tympani : tr. sec.
Auditory vesicle of embryo Rabbit : long. sec.
Cochlea of Guinea Pig : med. sec.
Nasal mucous membrane of Cat : tr. sec.
Nasal mucous membrane of Rabbit, respiratory portion.
Olfactory mucous membrane of Rabbit : tr. sec.
Circumvallate papillae of Ox : med. sec.
Papilla foliata of Rabbit : tr. sec.
Pacinian corpuscles in human skin.

Series 17. *Circulatory and blood-forming organs.*

Renal artery and vein of Pig : tr. sec. (fibres stained).
Renal artery and vein of Pig : tr. sec. (cells stained).
Human muscle of heart : tr. sec.
Embryo of Rabbit : tr. sec. in region of heart.
Human blood : film preparation.
Human blood : haemin crystals.
Red bone marrow of Pig.
Human spleen : sec.
Human thymus gland (child) : sec.
Lymphatic gland of Pig : sec.

Presented by C. L. CURTIES.

(Slides *remounted* by the late Sir Benjamin Ward Richardson over 50 years ago.)

X. 428. Medulla of Cat : tr. sec., injected.
429. Tongue of Rat : tr. sec., injected.
430. Duodenum of Turtle : tr. sec.
431. Intestine of Guinea Pig : vert. sec., injected.
432. Jejunum of Cat : vert. sec., injected.
433. Large intestine of Pig : tr. sec., injected.
434. Retina of Rat : injected.
435. Toe of Mouse : long. sec., injected.

X. 436. Human tooth : tr. sec.
437. Human large intestine : vert. sec., injected.
438. Human jejunum : vert. sec., injected.
440. Human sole of foot : vert. sec.

Freshwater Algae.

Presented by J. Burton.

B. 112. *Anabaena circinalis.*
122. *Apiocystis Brauniana.*
119. *Batrachospermum moniliforme.*
114. *Bulbochaete* sp.
117. *Chaetophora incrassata.*
116. *Choaspis stictica.*
126. *Chroöcoccus turgidus.* / *Coelosphaerium Kuetzingianum.*
115. *Cladophora flavescens.*
127. *Cladophora* sp. (Lake Zürich).
B. 121. *Clathrocystis aeruginosa.*
123. *Coleochaete scutata.*
125. *Cosmarium nitidulum.*
124. *Cylindrospermum stagnale.* / *Lyngbya* sp.
125. *Merismopedia* sp.
41. *Micrasterias rotata.*
128. *Oscillatoria princeps.*
113. *Pandorina morum.*
129. *Sphaeroplea annulina.*
118. *Spirogyra* sp.
120. *Tolypothrix lanata.*
130. *Trichodesmium Ehrenbergi* (Atlantic Ocean).
53. *Zygnema* sp.

Presented by Exor. of J. M. Allen.

B. 111. *Ballia pulchrinum.*

Diatomaceae.

Presented by S. E. Akehurst.

A. 690. *Amphipleura pellucida* (realgar).

Presented by J. BURTON.

A. 688. *Rhipodophora meneghiniana*, on *Ectocarpus*.
689. *Achnanthes* sp., conjugating on Marine Algae.

Purchased : mounted in styrax.

A. 691. *Actinocyclus pruinosus.*
692. *Actinoptychus Bismarckii.*
693. *Actinoptychus Grunowii.*
694. *Actinoptychus hexagonus.*
695. *Actinoptychus maculatus.*
696. *Amphora Grevillei.*
697. *Asterolampra aemulans.*
698. *Auliscus mirabilis.*
699. *Auliscus permagna.*
701. *Biddulphia Roperiana* (showing mode of growth).
702. *Biddulphia Tuomeyi.*
700. *Brebissonia Weissflogii.*
703. *Campylodiscus stellatus.*
704. *Clyphodesmis Challengerensis.*
705. *Cocconeis extravagans.*
706. *Diploneis exemeta.*
707. *Entogonia Daveyani.*
708. *Gymatopleura solea.*
709. *Hantzschia marina.*
710. *Mastogloia cruciata.*
712. *Navicula carinifera.*
711. *Navicula follis.*
713. *Navicula gemmulatula.*
714. *Navicula irrorata.*
715. *Navicula luxuriosa.*
716. *Navicula notabilis.*
717. *Nitzschia scalaris.*
718. *Omphalopsis australis.*
719. *Opephora Schwartzii.*
720. *Pinnularia dactylis.*
721. *Plagiogramma validum.*
252. *Pleurosigma balticum.*
722. *Podocyrtis adriaticus.*
723. *Raphoneis amphiceros.*

A. 724. *Stephanopyxis Campeachiana.*
725. *Stictodiscus Nova-Zealandicus.*
726. *Stictodiscus parellelus*, var. *gibbosa.*
727. *Surirella lata*, var. *robusta.*
728. *Surirella Macraeana.*
729. *Terpsinoe americana.*
730. *Triceratum definitum.*
731. *Triceratum favus*, var. *quadrata.*
732. *Triceratum favus*, var. *maxima.*
733. *Triceratum fractum.*
734. *Triceratum grande.*
735. *Triceratum Nova-Zealandicus.*
736. *Triceratum Robertsianum.*

Fungi.

Presented by J. Burton.

C. 190. *Sphoeria herbarum.*
191. *Sphoerella rusci.*

Bacteria.

Presented by J. Burton.

C. 140. *Cohnia roseo-persicina.*

Plant Structure.

Presented by C. J. H. Sidwell.

E. 38. Leaf of *Hydrocharis morsus-ranae* } Cellular structure.
37. Leaf of *Tradescantia virginica* }

E.A. 55. Leaf of *Croton zambesicus* } Hairs and glands.
58. Leaf of *Cynoglossum micranthum*
52. Leaf of *Onosma alboroseum*
57. Leaf of *Onosma stellulatum*
53. Leaf of *Onosmodium carolinianum*
24. Leaf of *Rhododendron Dalhousia*
56. Leaf of *Rhododendron Maddeni*
51. Leaf of *Trichodesma indicum*
54. Leaf of *Trichodesma khasiana*

Seeds.

Presented by C. J. H. Sidwell.

G. 43. *Anagallis arvensis.*
41. *Castilleja* sp.
46. *Castilleja Culbertsoni.*
43. *Cerastium glomeratum.*
39. *Delphinium macrocentron.*
47. *Linaria vulgaris.*
42. *Mohavea viscida.*
45. *Pedicularis Frederica-Augusti.*
44. *Picrorhiza Kurrooa.*
40. *Tricholoena rosea.*

PROCEEDINGS

OF THE

QUEKETT MICROSCOPICAL CLUB.

At the 497th ordinary meeting of the Club, held on March 24th, 1914, the President, Prof. A. Dendy, D.Sc., F.R.S., in the chair, the minutes of the meeting held on February 24th were read and confirmed.

Messrs. C. W. Engelhardt, Harry Albert St. George, E. Hermann Anthes, Felix R. W. Brand, Victor M. E. Koch, Francis W. Lloyd, Leonard R. Gingell and His Excellency Nicholas Yermoloff, K.C.V.O., were balloted for and duly elected members of the Club.

The list of donations to the Club was read, and the thanks of the members voted to the donors.

The President said: "My attention has been called to the fact that Mr. Powell, one of our oldest and best-known members, is present this evening. I am also informed that Mr. Powell celebrated his eightieth birthday on Saturday last. May I be allowed, on behalf of the Club, to offer him our sincere congratulations on this occasion, and to express our satisfaction that he is still able to be present at our meetings?"

Mr. J. W. Ogilvy (Messrs. Leitz) exhibited an illuminator for opaque objects which consists of a bull's-eye and a stage-condenser fitted to a bar which is carried on a stand having universal movements. Being in one piece, time is saved in setting up the apparatus.

Mr. N. E. Brown, A.L.S., read "Some Notes on the Structure of Diatoms."

An animated discussion followed the paper, in which the President and Messrs. O'Donohoe and Ainslie took part, and to which Mr. Brown replied.

A hearty vote of thanks was given to Mr. Brown for his interesting paper.

The Hon. Sec. read a paper, communicated by Mr. E. M. Nelson, F.R.M.S., on "A New Object-glass by Zeiss, and a New Method of Illumination."

Messrs. Zeiss exhibited the new oil-immersion 1/7th on four microscopes, and the thanks of the meeting were accorded to Messrs. Zeiss and to M. Koch, who represented the firm.

At the 498th ordinary meeting of the Club, held on April 28th, 1914, the Vice-President, Mr. D. J. Scourfield, F.Z.S., F.R.M.S., in the chair, the minutes of the meeting held on March 24th were read and confirmed.

Messrs. Edward Carlile, Francis Cooley-Martin, Gerald Burton Burton-Brown, M.D., Francis Edward Robotham and Daniel Arthur Davies, jun., were balloted for and duly elected members of the Club.

The list of donations to the Club was read and the thanks of the members voted to the donors.

The Hon. Sec. read a note on "A New Low-power Condenser," communicated by Mr. E. M. Nelson, F.R.M.S.

Mr. C. Lees Curties (Messrs. C. Baker) exhibited both the low-power condenser designed by Mr. Nelson and also a simple centring-stop holder which he had suggested.

Replying to a question, Mr. C. Lees Curties said that the aperture of the condenser was 0·55. On account of its long working distance, the condenser would be particularly useful for dark-ground illumination when examining pond-life in a trough.

Mr. M. A. Ainslie said that the Leitz achromatic condenser with the top off had an aperture of 0·6, and a working distance of one-third of an inch. He would suggest that, when necessary, the condenser should be decentred, in order to centre the stop. He frequently did this with low powers, when necessary.

Votes of thanks to Mr. Nelson and to Mr. Curties were proposed and carried unanimously.

Mr. N. E. Brown, A.L.S., gave an account—illustrated with fresh specimens of the flower and a coloured drawing of a longitudinal section—of "The Fertilisation of *Vinca minor*." He said that a very interesting microscopic object was concealed in this flower. As regards its fertilisation, a special interest was connected with the flower of the periwinkle. The fruit of this plant is extremely rare, not only in this country, but also on the Continent. The flower has a very remarkable structure, and a

section exhibiting the stigma has several points of interest. At the bottom of the tube are two large glands which secrete honey, one on each side of the ovary. The ovary has two carpels, which are separate, but are united at the top into a single style. This goes up, and at the top expands into a wing-like disc, and terminates with a crown of hairs like a sweep's brush. Some of these hairs turn down into five little tufts, forming little alcoves, which play very important functions. From the corolla arise five stamens. The anthers are raised above, and are so curved over as to enclose the whole and prevent ingress except between each pair of stamens. The anthers open while in the bud, and then shed their pollen, which, when the flower opens, is seen to be deposited in five little heaps. Underneath the wheel-like formation, often spoken of as a stigma, we find a frill-like, orange-coloured body, which is not of the same depth all round, but opposite the little alcoves already referred to deepens slightly. The true stigma is formed by this curtain, or frill, and there we find the true stigmatic tissue. Now as regards fertilisation. Insects (bees) come for the nectar situated at the base. Grooves guide the tongue between two anthers and past the upper ledge of the shelf, or frill. Here it passes the little masses of pollen, which are slightly glutinous, and, before reaching the honey-glands, comes in contact with a wet, viscid fluid. When the tongue is withdrawn, the smeared surface comes in contact with the mass of pollen, which adheres to it. But the plant does not want to part with all its masses of pollen, and so some is scraped off the proboscis by the projecting hairs, and remains until the visit of another bee, which, perhaps, has already visited a periwinkle flower. The tongue passes down past the stigmatic frill; but in coming back scrapes the pollen off on the under side, no trace of pollen remaining on the part of the tongue previously smeared with the viscid matter. This is the manner in which the plant is fertilised. Last year the speaker had examined many plants in order to see if they had been fertilised. It is commonly stated that *V. minor* is infertile to its own pollen, and so seeds are rare. Nearly all plants in one locality are probably products of one plant, and have not come from seed. Of the plants examined, 70 per cent. had been fertilised by insects; but no fruit of any kind developed on the clump under observation. Mr. Brown this year had fertilised one hundred flowers; but it is yet too early to

be able to report any results. This year was noticeable for a great dearth of pollen, all the anthers being more or less barren. He awaited with interest the result of his artificial pollination.

The Chairman said that at first thought it might possibly be a case of over-elaboration.

Mr. R. Paulson asked if Mr. Brown had cut sections to see if any of the pollen grains had thrown out tubes. He preferred to distinguish between the terms "pollination" and "fertilisation." As is well known, there are some plants in the British flora where pollination does take place, but which are infertile. As an instance he would mention the lesser celandine *Ranunculus ficaria*. Had Mr. Brown ever seen any seeds of this plant? It might be imagined that its seeds would be very numerous; but this is not the case. It does seem that in many plants we have instances of over-elaboration. He would instance orchids and violets—and especially with regard to violets. Violets produce abundant seed, not by the attractive flowers, but by little green flowers which are usually missed by the ordinary observer. These little green flowers never open and the anthers shed their pollen directly on to the stigmas.

Mr. C. E. Heath asked whether the pollen of *Vinca minor* had been seen to form tubes.

The Hon. Secretary suggested that the pollen might be tested practically, under the microscope, in a weak solution of sugar-and-water. If the grains did put out tubes, he thought it would prove the possibility of fertilisation.

Mr. Brown, replying, said that even if the pollen grains produced tubes in a sugar-and-water solution, it would be no guarantee that they would also do so in the flower. He intended, however, to examine the pollen and also to cut sections. Regarding the celandine, in the South of England it seeds quite freely. It is possibly a question of temperature. Not all violas have cleistogamous flowers; some usually produce seed from the ordinary open flowers.

The Hon. Secretary (Mr. James Burton) read a note on "An Abnormal Form of *Arachnoidiscus ornatus*." He wished to draw attention to the plate of Arachnoidiscus, by Beck, in Carpenter's *The Microscope and its Revelations*, a copy of which was on the table. The drawing represented the diatoms entire and still attached to the seaweed on which they occurred. It showed their

living form. That which we are accustomed to find on mounted slides is only a part of the organism. He was exhibiting, under a microscope, a slide given him by Mr. Williams, of Folkestone, which displayed very beautifully the box-like form of this diatom. It consists of a top and a bottom circular plate, known as valves, to each of which is attached a ring, called by some authors the girdle; that of the top—or lid, as it might be called—fitting outside that of the lower, or box-like, part. The whole closely resembles an ordinary circular "chip" specimen-box. On the slide exhibited, examples of an abnormal form occur, in which the bottom of the box has the "girdle" greatly elongated, the "lid" still remaining shallow, as in a normal form. This structure gives the diatom, when viewed sideways, the appearance of a cylinder, instead of that of a disc with but slight depth, and when observed under a binocular with dark-ground illumination the difference is very striking. The girdle is marked by circles of lines running round, as though it were composed of superimposed rings. On the rings are small projections or points. The frustules are empty, and there is no appearance of the commencement of dividing-walls inside, which might have indicated that the unusual form was owing to the beginning of the process of subdivision. In a normal form the depth was 30 μ; in a case where subdivision was far advanced the depth was 54 μ. In an abnormal specimen the depth was 96 μ; another was 105 μ. The diameter in all the forms measured is fairly constant, varying from 105 μ to 114 μ. The abnormal form is only known to occur in one collection of material from Mauritius, and in that the percentage is very small. No explanation or suggested cause of the unusual form was forthcoming.

Mr. Burton was complimented on the opportunity of bringing this interesting slide under the notice of members.

Several members had interesting exhibits under microscopes, Mr. G. K. Dunstall showing *Floscularia cyclops*, which is worthy of being recorded.

At the 499th ordinary meeting of the Club, held on May 26th, 1914, the President, Prof. A. Dendy, D.Sc., F.R.S., in the chair, the minutes of the meeting held on April 28th were read and confirmed.

Messrs. Henry Turing Peter, Sydney G. Bills and Robert

William Buttemer were balloted for and duly elected members of the Club.

The list of donations to the Club was read and the thanks of the members voted to the donors.

Mr. W. R. Traviss exhibited a number of specimens of insects in amber.

Mr. A. E. Hilton read "Some Notes on the Cultivation of Plasmodia of *Badhamia utricularis*." He said that a free-flowing mass of naked and almost undifferentiated protoplasm, such as we have in a plasmodium of *B. utricularis*, suggests opportunities for biological experiments with unusual promise of success.

The chief purpose of this paper, Mr. Hilton said, was to place on record the results of experiments made during the last few months, which suggest a method of continuous cultivation of plasmodia of *B. utricularis* at once simple and practicable.

The President said they were very much obliged to Mr. Hilton for his very interesting and practical paper, which he should find of great value to himself, as he had hitherto had great difficulty in feeding this organism. He hoped the methods described would come into general use for laboratory work, where the plasmodium was very useful as an illustration. He should like to ask Mr. Hilton if he had tried how long he could keep the plasmodium in a dry state on the blotting-paper. Mr. J. J. Lister at Cambridge used to feed it on fungus, but this was sometimes difficult to get. He hoped that many members of the Club would experiment in the manner suggested.

Replying to several questions, Mr. Hilton said the dried sclerotium is capable of reviving after at least three years; but it must be kept dry, and never allowed to become damp. After so long a period, it might take four or five days to recover. He could not say if it were possible to cultivate the plasmodium form from sporangia. A difference in colour has been noticed in specimens cultivated on plain bread compared with specimens fed on the special mixture. The former are a lighter yellow than the latter; but various shades of yellow are present even in one plasmodium. He had found a constant temperature of about 50° F. the best.

A very hearty vote of thanks was accorded to Mr. Hilton for his paper.

The Hon. Secretary read a paper on "Binocular Microscopes," communicated by Mr. E. M. Nelson, F.R.M.S. In recent years several binoculars have been introduced, none of which, however, can be called new. The first, the Greenough, by Zeiss (*Journal R.M.S.*, 1897, pp. 599, 600), was a twin microscope—a form of binocular invented by Père Cherubin d'Orléans nearly three hundred years ago. The second—by F. E. Ives, in 1902 (*Journal R.M.S.*, 1903, p. 85)—is very similar to one designed by Wenham in 1866 as a counterblast to Powell's high-power binocular, in which the whole beam is sent into each eye. The third, a modification of the second, by Leitz (*Journal R.M.S.*, 1914, p. 5), and the fourth, by Beck, which is very similar to that of Ives.

Mr. Nelson concluded his paper by some remarks on the position of the two new binoculars. From what has been said, it will be seen that they are a class by themselves. It would be quite inaccurate to entertain the idea that these instruments are a new kind of stereoscopic binocular constructed to enter into competition with, and finally to supersede, existing binoculars of the Wenham and Stephenson type, for they only possess the first attribute—stereoscopism—in a limited manner. Their use is confined to the employment of full Ramsden discs in each eye—that is, for work with non-stereoscopic images. When prolonged work is undertaken with one of the new binoculars, great relief and comfort to the eyes will be secured.

Messrs. Beck, represented by Mr. C. Beck and Mr. Creese, exhibited two of their new model high-power binoculars, one giving an excellent image of *Pleurosigma angulatum* with a 1/12th oil-immersion, and on the other stand a lower power exhibited to perfection, first, stereoscopic, and, second, pseudo-stereoscopic vision obtained by altering the tube-length. Mr. Creese also exhibited a Wenham binocular with a 1/6th objective, giving a perfectly evenly illuminated field at 300 diameters of a section of the eye of the drone-fly.

Messrs. Leitz's London representative, Mr. J. W. Ogilvy, showed seven stands of their new model, with powers ranging from 1/12th oil-immersion apochromat and 1,500 diameters to 1 in. and × 35. Two Leitz-Greenough models with low powers were also exhibited. The preparations shown included *Amphipleura pellucida*, Podura scale, rock sections, and histological preparations.

Mr. Nelson also sent for exhibition a photograph of a new slide, designed by Mr. G. Nelson, for the portable Greenough, to hold three pairs of objectives. It allows the powers to be changed by moving the slide forward, and, in brief, is for the Greenough what a rotating nosepiece is for an ordinary microscope.

At the 500th ordinary meeting of the Club, held on June 23rd, 1914, the Vice-President, Mr. E. J. Spitta, L.R.C.P., M.R.C.S., in the chair, the minutes of the meeting held on May 26th were read and confirmed.

Messrs. Geoffrey Norman, Charles James Reeves King, William Henry Scott, Charles Worthington Hawksley, Martin Herbert Oldershaw and Edmund John Weston were balloted for and duly elected members of the Club.

The list of donations to the Club was read and the thanks of the members voted to the donors.

Mr. Watson Baker, jun., read a short paper describing a series of sections of fossils from the Coal Measures. Many of these were not only rare, but were almost unique in the beautiful manner in which they showed the various structures, both of plants and animals. They were exhibited under a number of microscopes, lent and arranged for the occasion by Messrs. Watson & Son. There were on view, also, whole specimens still attached to the rock in which they were found. Mr. Watson Baker said the specimens had been sent to him by a well-known authority on palaeo-botany, and as many of them were of unusual merit, he thought the Club would like to see them. He then gave an interesting description in some detail: a condensed account is as follows: No. 1. A specimen of the lower jaw of Elonicthys, with teeth *in situ*. No. 2. Flank scales from the same. Elonicthys is a genus of fishes having a bony armour or a skeleton. Devonian and Carboniferous, they existed in large numbers and great variety, some attaining a great size. No. 3. A specimen of the Caeleanthidae (hollow-spined fishes), which range from the Upper Devonian to the Chalk. Specimens of these *in situ* were on the table. Nos. 4 and 5 were sections of teeth of species of shark, *Diplodus equilateralis* and *D. gibbosus*; also an uncut example of one of the teeth. Nos. 6 and 7. Sections of coal from Mossfield Colliery, Longton, showing various vegetable tissues.

Microspores and Megaspores—reproductive organs resembling those of modern Lycopods were clearly evident. No. 8. Plant remains of a similar character. No. 9. A number of Fern sporangia, showing the annulus, etc., embedded in a matrix of fragmentary plant remains. No. 10. A section showing the seeds of Cordaites: a genus of fossil-plants allied to some of the recent Gymnosperms.

The chairman remarked on the very beautiful series of microscopical slides, and on the hand specimens on the table, and proposed a vote of thanks to Mr. Watson Baker, which was responded to heartily.

The Hon. Secretary read a letter from Dr. M. C. Cooke, and extracts from others received from Alphaeus Smith, Albert D. Michael and G. C. Karrop, who were unable to be present, congratulating the Club on its continued prosperity, and wishing it all success in the future. These were received with much appreciation by the meeting.

The chairman then gave a short *résumé* of the history of the Club. He said that though named in honour of the celebrated Dr. Quekett, it was not founded by him, originating four or five years after his death. It was considered by a Mr. Gibson that an association of amateur microscopists was desirable, and he put an announcement into *Hardwicke's Science Gossip* to that effect. The idea at first seemed to be to combine music and microscopy at the evening meetings. The suggestion was rapidly and enthusiastically taken up, and in July 1865 the Club was definitely started. Soon the meetings came to be held at University College; but it is curious to note that some of the preliminary ones were held in Hanover Square, so that, again occupying rooms in Hanover Square, the Club has returned to its old locality. Among the very earliest members Mr. Lewis's name appears. He was elected in April 1866—forty-eight years ago, and has held the position of honorary reporter from the very early years of the Club. He has attended 485 out of the 500 ordinary meetings—almost certainly a record—and several of the omissions occurred only this last winter, owing to illness and advancing years. Another very old member is Mr. Alphaeus Smith, who held the post of hon. librarian for forty years, and is still a member, though not on the active list. Dr. M. C. Cooke, Mr. J. Terry, Mr. T. H. Powell, and

Mr. Millett all joined in 1865, and are still members. Dr. Spitta referred to the work of Dr. Karop and Mr. Earland, both of whom had been hon. secretaries in former years, and to whom the Club was greatly indebted for its success. Lantern photographs of Dr. Quekett and of pages of the old attendance-books, showing names of original members, and various scenes connected with the Club's life, were thrown on the screen. Dr. Spitta wound up his interesting and delightfully humorous discourse by recounting a supposed reverie (in verse) in which he saw most of the present officers and prominent members coming into a meeting, and detailed with delicate skill and good nature their hobbies and characteristics. He then called upon some of the older members—of whom a satisfactory number had been able to attend—to say a few words.

Mr. Lewis made a little speech, in which he disclaimed the title of "veteran," as he said Mr. Powell was before him, and he spoke of Mr. A. Smith, who joined just after him. He was able in some respects to supplement the chairman's remarks of what took place at the earliest meetings, and said in conclusion that "though my recent illness has shaken my health, and I shall have to give up many things, the last I shall give up will be the Quekett Microscopical Club, from which I have derived much information, and have made many old and valued friends, and no one connected with the Club has its interests more at heart than myself." His remarks were received with enthusiasm by the members, who showed their appreciation by prolonged cheers.

Mr. T. H. Powell (forty-nine years a member) wound up what he said by remarking that he always enjoyed himself at the pleasant meetings of the Quekett. Mr. F. Enock addressed the meeting appropriately, and was followed by Mr. Earland, who made an interesting and humorous speech on some of his experiences as secretary. He, like others, referred to Mr. Lewis, and rejoiced to see him still at the seat at the reporter's table he had occupied so long. Again the audience showed their appreciation by cheers. Mr. Hilton followed. He pointed out that till quite recent years, during the long career of the Club, there had been only two librarians, owing to Mr. Smith's long tenure of the office. He also remarked on the large attendance at the meetings now, saying that they could not realise what it was to have a meeting with only six or even fewer present; but stated that there was

no less good will and friendliness among them now, and desire to help and welcome new-comers. He felt it had been a great advantage to himself to belong to the Club.

The chairman then proposed a rhyming "toast," wishing "Long life to the Club," and, at his request, the members rose in a body and "made the welkin ring" in their concurrence with the sentiment he had so deftly expressed.

To wind up a very pleasant evening, Dr. Spitta exhibited upon the screen a series of lantern views of natural objects, beautifully nature-coloured. Many of various flowers were wonderful productions, with the colours unbelievably soft and lifelike, and some of the insects were not less successful. The meeting then broke up, many staying, however, to examine more leisurely Mr. Watson Baker's unique specimens.

Unfortunately too late to be read at the meeting, a Marconigram arrived from the late hon. secretary, Mr. W. B. Stokes, at Montreal: "Congratulations five hundredth meeting." (Signed) Stokes.

OBITUARY NOTICE.

MORDECAI CUBITT COOKE, M.A., LL.D., A.L.S.

(*Born July 12th*, 1825; *died November 12th*, 1914.)

It is with feelings of great regret we have to record the death, in his ninetieth year, of Dr. M. C. Cooke, the "Father of the Club," which took place on November 12th at his residence in Southsea.

Dr. Cooke was born in 1825 at the village of Horning in Norfolk, where his parents kept a general shop. From an early age he was dependent upon his own resources, and was in turn employed as draper's assistant, teacher in a National school and lawyer's clerk. As an assistant in the Indian Museum he at last found congenial occupation, and when that institution was abolished spent some time at the South Kensington Museum, in the Mycological Department. He afterwards joined the Herbarium at the Royal Botanic Gardens, Kew, and was for twelve years (1880-92) in charge of the Cryptogamic Department; in the latter year he retired on a pension.

During this time he incorporated his own herbarium, containing 46,000 specimens, with the existing collection at Kew, as well as the collection of fungi presented to Kew by the Rev. M. J. Berkeley. His figures of fungi, mostly coloured and numbering 25,000 plates, are also at Kew.

His first important work was the *Handbook of British Fungi*, in two volumes, published in 1871, followed by *Mycographia*, or, coloured figures of fungi from all parts of the world, 113 plates; *Handbook of Australian Fungi*; and *Illustrations of British Fungi*, 1,200 coloured plates. In addition to the above, over 300 articles on mycological subjects are credited to Dr. Cooke by Lindau and Sydow; for a period of fifteen years he also edited *Grevillea*, a journal devoted to cryptogamic botany.

After his retirement in 1892 Dr. Cooke retained his interest in fungi, and until 1904 attended the annual fungus foray of the Essex Field Club. Recently his eyesight failed, though his mind remained keen and active. He was honorary M.A. of Yale, and

LL.D., and in 1903 he had the honour of being awarded the gold medal of the Linnean Society.

In addition to his scientific publications, he was the author and editor of a number of popular books in Natural History, and was at the time associated with the publisher of Hardwicke's *Science Gossip*, of which journal he was editor from its beginning in 1865 until December 1871.

In the *Journal of the Q.M.C.* for November 1899 will be found "Early Memories of the Q.M.C.," a short paper contributed by Dr. Cooke on the early history of the Club. Dr. Cooke was one of the eleven members who attended the preliminary meeting held on June 14th, 1865, and the meeting on July 7th, when the Q.M.C. originated, and he was then elected one of its first Vice-Presidents. He was President in 1882 and 1883, and was elected an honorary member in 1893. He was always a very active spirit at committees, meetings and excursions as long as he attended; his last recorded attendance was in May 1900.

Many of us will recall that our first excursions into the fairy-land of science were made under the guiding hand of Dr. M. C. Cooke.

TABLE FOR THE CONVERSION OF ENGLISH AND METRICAL LINEAR MEASURES; YARD AND METRE AT SAME TEMPERATURE.

1 ÷	mm.	1 ÷	μ	1 ÷	μ	1 ÷	μ	1 ÷	μ
2	12·70	27	940	53	479	79	321	125	203
3	8·46	28	907	54	470	80	317	130	195
4	6·35	29	876	55	462	81	313	135	188
5	5·08	30	846	56	453	82	310	140	181
6	4·23	31	819	57	445	83	306	145	175
7	3·63	32	794	58	438	84	302	150	169
8	3·17	33	769	59	430	85	299	155	164
9	2·82	34	747	60	423	86	295	160	159
10	2·54	35	725	61	416	87	292	165	154
11	2·31	36	705	62	410	88	289	170	149
12	2·12	37	686	63	403	89	285	175	145
13	1·95	38	668	64	397	90	282	180	141
14	1·81	39	651	65	391	91	279	185	137
15	1·69	40	635	66	385	92	276	190	134
16	1·59	41	619	67	379	93	273	195	130
17	1·49	42	605	68	373	94	270	200	127
18	1·41	43	591	69	368	95	267	205	124
19	1·34	44	577	70	363	96	265	210	121
20	1·27	45	564	71	358	97	262	215	118
21	1·21	46	552	72	353	98	259	220	115
22	1·15	47	540	73	348	99	256	225	113
23	1·10	48	529	74	343	100	254	230	110
24	1·06	49	518	75	339	105	242	235	108
25	1·02	50	508	76	334	110	231	240	106
	μ	51	498	77	330	115	221	245	104
26	977	52	488	78	326	120	212	250	102

As the measurements of many microscopical objects are given in fractions of an inch in English literature, and in metrical measure in foreign works, the above table has been drawn up to facilitate comparison. Its use is obvious. Examples: 1/7th inch = 3·63 mm., 1/58th inch = 438 μ, or ·438 mm. For fractions smaller than 1/250th inch that portion of the table between the figures 26 and 99 may be used by cutting off the last figure for hundredths, and the two last figures for thousandths. Examples: 1/270th inch = 94·0 μ, or ·0940 mm.; 1/7900th inch = 3·21 μ, or ·00321 mm. When that portion of the table between the figures 100 and 250 is used it is only necessary to cut off the last figure for thousandths and the two last figures for ten thousandths. Examples: 1/1350th inch = 18·8 μ, or ·0188 mm., 1/16500th inch = 1·54 μ, or ·00154 mm. The conversion of millimetres into fractions of an inch is performed in the same manner; thus, 529 μ or ·529 mm. = 1/48th inch; 39·7 μ or ·0397 mm. = 1/640th inch; 2·62 μ or ·00262 mm. = 1/9700th inch; 1·04 μ or ·00104 mm. = 1/24500th inch; ·977 μ or ·000977 mm. = 1/26000th inch, and so on.—E. M. N.

THE EARLY HISTORY OF THE QUEKETT MICROSCOPICAL CLUB.

By R. T. Lewis, F.R.M.S.

The Quekett Microscopical Club this year attains its Jubilee, and, as no doubt many of its present members are unacquainted with its early history, it has been thought that some account of this would be of interest.

Hardwicke's *Science Gossip* was started in January 1865, and in the May number of that periodical a letter appeared from Mr. W. Gibson, suggesting that a Society for Amateur Microscopists on similar lines to those of the Society of Amateur Botanists (of which he was a member) would be desirable, as being a means of bringing together those having similar tastes, who could meet to discuss difficulties and assist one another in a manner not provided for by the existing Society. Monthly meetings and a small subscription were proposed, and persons interested in the matter were invited to co-operate. The Editor of *Science Gossip* gladly inserted this communication, and, being himself the President of the Society of Amateur Botanists at the time, entered fully into the project, and together with Mr. W. M. Bywater and Thomas Ketteringham met at the house of the former in Hanover Square, and having discussed its feasibility, decided that such a society should be established, and should be named "The Quekett Club" after the name of the distinguished Professor of Histology * who had died a short time previously.

* John Thomas Quekett, b. 1815. In 1856 he succeeded Prof. Owen as Conservator of the Hunterian Museum, and was appointed Professor of Histology, which post he held until his death. He was elected F.R.S. in 1860, and died in 1861. He was Secretary of the Microscopical Society of London for nineteen years. His *Practical Treatise on the Use of the Microscope* is, or was, well known.

A meeting of twelve gentlemen known to be interested in the microscope was therefore called, and took place on June 14th, 1865, at the offices of Mr. Robert Hardwicke in Piccadilly. This meeting was attended by eleven out of the twelve summoned, the chair was taken by Mr. M. C. Cooke, and on the motion of Mr. W. Gibson it was unanimously resolved that such a Club should be formed, and on the motion of Mr. E. Jaques it was also unanimously decided that a provisional Committee of five gentlemen, with Mr. Bywater as Secretary, should be appointed, and charged with the duty of deciding as to the best means of carrying out the object in view, and to report the result of their deliberations to an adjourned meeting to be held on July 7th. This meeting, which was held at St. Martin's National Schools, was attended by about sixty gentlemen, when four suggestions made by the Committee were discussed and severally put to the meeting, it being eventually decided :

(1) That the new society should be called the Quekett Microscopical Club.

(2) That the meetings be held on the fourth Friday of every month.

(3) That the subscription be 10*s.* per annum, payable in advance, and be considered due as from July 1st, 1865.

(4) That the business of the Club be conducted by a President, two Vice-Presidents, twelve Members of Committee, a Secretary and a Treasurer.

It was further decided that the provisional Committee should be empowered to carry on the business of the Club and to receive subscriptions until the appointment of regular officers had been duly made ; the meeting was then adjourned until August 4th, 1865. At the adjourned meeting, which was also held at St. Martin's Schools, a series of eleven By-laws were passed, Dr. Edwin Lankester was elected the first President of the Club, with Messrs. M. C. Cooke and P. le Neve Foster as Vice-Presidents, Mr. Robert Hardwicke as Treasurer, Mr. W. M. Bywater

Secretary, and twelve members to serve on the Committee. The first Ordinary Meeting was held on August 25th, 1865, in the rooms at 32, Sackville Street, when the President took the chair and gave an interesting inaugural address, and the Quekett Microscopical Club was thus fairly started on what has proved to be a successful career. The rapid increase in the number of members soon made it apparent that the room in Sackville Street was not large enough for the purpose, and the Eighth Ordinary Meeting was held in the Library of University College, kindly placed at the disposal of the Club by the Council of the College, through whose courtesy the meetings continued to be held there until 1889. Dr. Lankester was succeeded in the Presidency by Mr. Ernest Hart, and it was in October 1866 that the suggestion was made that the proceedings of the Club were now of sufficient importance to deserve some record, and in the following month reports were taken by Mr. R. T. Lewis, who has carried out this duty to the present time. The earlier papers read at the meetings were in some instances published in the *Microscopical Journal* or in *Science Gossip*, but they were subsequently printed in the *Journal* of the Club, which was commenced in 1868 under the editorship of Mr. W. Hislop.

The first Soirée of the Club was held at University College on January 4th, 1867, and notwithstanding a heavy fall of snow and frost of exceptional severity, in consequence of which vehicles were only to be obtained at a high premium, it was attended by a large number of members and their friends, and was deemed to have been a decided success. Profiting, however, by the experience gained on this occasion, future Soirées were held somewhat later in the year. The number of members at the end of the second year of the Club's existence was 273. Eleven Field Excursions took place, the Cabinet contained 260 slides, and an "Exchange of Slides Committee" was appointed.

Mr. Arthur E. Durham was the third President, and held the office for two years, during which period the *Journal* of the Club made its first appearance, the extra meetings on the second Friday in each month were commenced, and the first dinner took place at Leatherhead, Mr. Suffolk's classes * were restarted, and the number of members was reported as having reached 512. It was towards the beginning of 1868 that a member of the Committee began to agitate for the admission of women as members, a proposal strongly deprecated by his colleagues as being subversive of the interests of the Club. This gave rise to considerable opposition from the members generally, and much merriment was created by the circulation of sketches by Mr. Suffolk and Mr. Lewis, and by the issue of a skit purporting to be the report of a meeting held two years ahead and embodying most of the objections to the scheme. It was, however, formally proposed at the Ordinary Meeting in March 1868, Dr. Tilbury Fox in the chair, but on the resolution being put it found only two supporters, and was therefore negatived by an overwhelming majority.

At the Annual Meeting in 1869 Mr. P. le Neve Foster succeeded Mr. Durham as President, but the latter took the chair at the November meeting, when a handsome testimonial was presented to Mr. Bywater on his retirement from the position of Secretary, the duties of that office having been taken over by Mr. T. C. White. In 1870 the members had increased so much that it became necessary to reduce the number of invitation tickets issued for the Annual Soirée, a charge being made for

* Mr. W. T. Suffolk conducted a class for beginners during the winter of 1865–6 in a room at the Society of Arts, kindly placed at his disposal for the purpose by Mr. P. le Neve Foster. At this he gave useful and practical information on the management of the microscope, the mounting of objects, etc. The class was suspended during the summer months, but was resumed during the winter of 1866–7, and was fairly well attended but as there is no later mention of it, I infer that it was not again started, but occasional demonstrations at the Gossip Meetings seem to have taken its place.

those wanted in excess, the sale of which realised £5 7*s.* 6*d.*, and this was given as a donation to University College Hospital. The next four Presidents, Dr. Lionel S. Beale, Dr. Robert Braithwaite, Dr. John Matthews and Mr. Henry Lee, each held the office for two years. At the Annual Meeting in 1873 Mr. White retired and was succeeded by Mr. J. E. Ingpen, with Mr. E. Marks as Assistant Secretary. Mr. Robert Hardwicke, the first Treasurer of the Club, died in 1875, and was succeeded in the office by Mr. F. W. Gay. In 1878 Prof. T. H. Huxley was elected President, being followed by Dr. Spencer Cobbold in 1879, Mr. T. C. White in 1880 and 1881, Dr. M. C. Cooke in 1882 and 1883, Dr. W. B. Carpenter in 1884, Mr. A. D. Michael in 1885, 1886 and 1887, and Mr. B. T. Lowne in 1888-9. The date of the Annual Meeting was altered to the last Friday in February in 1888.

The last meeting in the Library of University College was held on February 22nd, 1889, but the Council of the College generously placed their Mathematical Theatre at the disposal of the Club. This room, however, was found unsuited to their purpose, and arrangements were made for removal to 20, Hanover Square. This necessitated a change of the meeting nights to first and third Fridays, and no Ordinary Meetings were afterwards held in July and August. The history of the Club during the last twenty-four years need not be recorded here, as all particulars are to be found in the reports, and are doubtless well known to the majority of the members. Briefly, however, since its commencement in 1865, it has had twenty-three Presidents, seven Secretaries, and has published sixteen volumes of its *Journal*.

Of the original members but few are now left, and of those who joined in the first year only two now are seen at the meetings. Mr. W. Gibson, whose suggestion led to the Club's formation, does not appear to have contributed to the proceedings, though he continued to be a member for eighteen

years. Mr. M. C. Cooke, who took the chair at the preliminary meetings, was elected an honorary member in 1893, and continued to take a lively interest in the well-being of the Club up to the time of his death, which occurred in his ninetieth year, only a few months ago.

A NEW COPEPOD FOUND IN WATER FROM HOLLOWS ON TREE TRUNKS.

By D. J. Scourfield, F.Z.S., F.R.M.S.

(*Read November 24th*, 1914.)

Plates 24 and 25.

The search for plants and animals in unusual and unlikely places is always interesting, and may be sometimes richly rewarded. As a case in point, and the one which led directly to the discovery of the new species of Copepod that I wish to describe in this paper, we may consider what has been done in the elucidation of the fauna living in the little natural cups formed by the bases of the leaves of plants belonging to the Order Bromeliaceae, *i.e.* the order to which the pine-apple belongs.

It was in 1879 that the celebrated naturalist Fritz Müller, who was at that time associated with the National Museum in Rio de Janeiro, called attention to the fact that the water contained in the little cups just referred to was tenanted by various forms of animal life. In particular he described a new Ostracod, representing a new genus, *Elpidium bromeliarum*, which occurred almost constantly in association with the Bromeliaceous plants in the forests of Brazil, and strangely enough was to be found in no other situation (**5**, **6**, and **7**).

Since that date a number of other investigators have from time to time examined these little collections of water retained by the leaves of Bromeliaceous plants, and I may here mention that soon after I became acquainted with the work of Fritz Müller I commenced to look for Entomostraca in these situations at the Royal Botanic Gardens, Regent's Park, and at Kew. My curiosity was gratified by finding the remarkable blind Copepod, *Belisarius viguieri*, which had not previously been found in this country.* In recent years still more attention

* Recorded and figured in *Journ. Q. M. C.*, vol. viii., November 1903, p. 539, and vol. ix., April 1904, Pl. 2 (**15**). For further notes on this species see also *The Wild Fauna and Flora of the Royal Botanic Gardens, Kew*, p. 20 (**16**).

has been given to the subject owing to the endeavour to discover the life-histories of mosquitoes and other insects supposed to be connected with the dissemination of tropical diseases. Last year a very elaborate paper was published by Picado (**8**), in which he gives details of the facts previously elucidated, and of his own work on this subject in Costa Rica. It appears that no less than about 250 species of animals have been found living in this peculiar environment, 49 being new to science. They belong to almost all groups of Invertebrates, but naturally insects and their larvae predominate. The Amphibia are also represented. A very full account of this paper has been recently published by H. Scott in the *Zoologist* (**12**).

When once this peculiar habitat had been pointed out, it was natural that somewhat similar situations should be searched, and records have indeed been made of animals found living in the pitchers of Pitcher-plants and Sarracenias, the holes occurring occasionally in bamboos, the tops of palm trees, and in various other places.

It occurred to me that perhaps the little collections of water which are sometimes to be found in the hollows and crevices on the trunks and exposed roots of trees might possibly be inhabited by some member or members of the Entomostraca, the group in which I am more particularly interested. This proved to be the case; at least I am now able to report that on several occasions I have found the minute Copepod about to be described in such little reservoirs of water on trees in Epping Forest. Up to the present it has been found nowhere else, and, on the other hand, I have never found any other species of Entomostraca in the same places.

The new species evidently belongs to the Harpacticid genus *Moraria* T. and A. Scott, and I propose to call it *M. arboricola* on account of its tree-dwelling habit.

The genus *Moraria* is very closely allied to the well-known genus *Canthocamptus*, and is, in fact, even now included in the latter by some authors. It was instituted by T. and A. Scott in 1893 (**14**) for a species found in Loch Morar, in Scotland, which they named *M. anderson-smithi*, believing it to be new, but which subsequently proved to be identical with *Canthocamptus brevipes* Sars, described thirty years previously (**11**). A month or two later in the same year, 1893, Mrázek described as new

the same species, placing it with two others which were really new to science, in a new genus, *Ophiocamptus*, thus showing that he also recognised the necessity of separating Sars's *C. brevipes* and closely allied forms from the old genus *Canthocamptus* (**4**).

The characteristics of the genus *Moraria* are chiefly as follows: Body very elongated, almost vermiform. Rostrum broad. First antennae seven-jointed. First four pairs of feet with three-jointed outer and two-jointed inner branches. Inner branches of first pair of feet only a little shorter than the outer branches, with the basal rather longer than the terminal joint. Inner branches of the second, third, and fourth pairs of feet only a little longer than the first joint, or at most only as long as the first two joints of the outer branches. Furca well developed, each branch tapering considerably from base to tip, and usually (? always) furnished with a strong longitudinal chitinous ridge on the dorsal surface.

So far as I can ascertain, eight species of *Moraria* have hitherto been described and two others referred to, but not described. They are as follows:

M. brevipes (G. O. Sars), 1863 = *Canthocamptus brevipes* G. O. Sars, 1863 (**11**); *M. anderson-smithi* T. and A. Scott, 1893 (**14**); *Ophiocamptus sarsi* Mrázek, 1893 (**4**).

M. mrázeki T. Scott, 1903 (**13**), new name only = *Ophiocamptus brevipes* Mrázek, 1893 (**4**).

M. poppei (Mrázek), 1893 (**4**) = *O. poppei* Mrázek, 1893 (**4**).

M. muscicola (Richters), 1900 (**9**) = *O. muscicola* Richters, 1900 (**9**).

M. schmeili van Douwe, 1903 (**3**).

M. mongolica (Daday), 1906 (**1** and **2**) = *O. mongolicus* Daday, 1906 (**1** and **2**).

M. wolfi Richters, 1907 (**10**).

M. quadrispinosa Richters, 1907 (**10**).

M. sp. 1 Richters, 1907 (**10**).

M. sp. 2 Richters, 1907 (**10**).

Most, if not all, of the above have been found living in wet or damp mosses; some, in fact, have hitherto been found in no other situations. Only the first three have been found in the British Isles.

Moraria arboricola sp. nov.

Female.—Body (fig. 1) long and vermiform, divided into nine free segments, the first being the longest and the sixth (first abdominal) the second in length. Rostrum broad. Eye red or brownish red, moderately large as a rule, but rather variable in size and in outline. Dorsal plate on carapace rather variable in shape, usually more or less rectangular with rounded angles, slightly broader in front than behind. Posterior margins of all segments smooth on dorsal surface. On ventral surface abdominal segments (fig. 16) armed as follows: 1st, with two widely separated groups of about five teeth; 2nd, with a row of teeth from one-third to half width of segment, sometimes with central teeth missing, thus leaving two isolated groups; 3rd, with a row extending almost across segment; 4th (last), with a row completely across segment and a little way round sides, except for the slight interruption caused by the posterior median notch. Anal plate or operculum (see fig. 15) more or less semicircular, with smooth but slightly wavy edge, and with faint dark and light bands radiating towards the edge, showing probably that the plate is very slightly corrugated.

In the stage before the adult the edge of the anal plate is not smooth, but furnished with a few very minute teeth, widely but somewhat irregularly spaced (fig. 13). In the still earlier stages the teeth are rather larger (fig. 12). The presence of teeth on the anal plate in the young stages of *M. brevipes*, which also has smooth edges in the adult, has been noted by Mrázek (**4**).

Branches of furca (figs. 14 and 15) moderately long and tapering considerably, with a prominent chitinous ridge on the dorsal surface, ending posteriorly in a blunt tooth from the base of which springs a spine directed upwards. Outer edges armed with two strong spines, the proximal with a minute accessory spine at its base. Inner edges with two curved rows of minute teeth, terminating dorsally in little teeth on the chitinous plate. Posterior edges with a row of teeth on the ventral surface, covering bases of terminal setae. Terminal setae usually quite smooth, three on each furcal lobe, inner very small, outer not quite half the length of the median, which again is about half the body length. The outer and median setae, especially the latter, somewhat bulbous at the base.

First antennae (fig. 2) rather short and seven-jointed, with the olfactory seta on the fourth joint reaching only to about the middle of the last joint. Second antennae of the usual type with the accessory branch (fig. 3) very small, one-jointed, bearing three setae at the tip. First pair of feet (fig. 4) small, with three-jointed outer and two-jointed inner branches. Inner branch not quite so long as outer, with one of the two terminal setae extremely long and curved at the tip. Second, third, and fourth pairs of feet (fig. 6) very similar to one another with the three-jointed outer branches larger than in the feet of the first pair, but with the two-jointed inner branches smaller, being only a little longer than the basal joints of the outer branches. The second joints of the inner branches of the second and third pairs of feet carry three terminal spines, the corresponding joint of the fourth pair only two. Fifth feet (fig. 8) consisting of two joints, the basal being extended on the inner side considerably beyond the broadly ovate second joint. Inner part of basal joint armed with six spines somewhat flattened, with rounded tips of the type found in *M. brevipes* Sars, but not quite so broad or blunt. The fourth and fifth spines from the inner edge arise from a little sub-rectangular projection which has the appearance of a pseudo-joint. A finely pointed spine projecting outwards arises as usual from the lower corner of the outer edge of the joint. The second joint armed with four spines, the innermost being of the same type as those on the basal joint, and the other three being finely pointed and not flattened. The median of these three turns outwards across the outer spine. There is a little thorn on the inner edge of this joint just above the innermost spine. None of the spines on the fifth feet are plumose, but a single barb usually occurs on the fifth and sixth from the inner edge, as indicated in fig. 8. Earlier stages of the fifth feet are shown in figs. 10 and 11.

Receptaculum seminis (fig. 18), lying immediately behind and usually covered by the fifth feet, somewhat complicated in structure, consisting apparently of two lateral highly chitinised convoluted chambers or tubes and a median membranous or muscular cavity, the latter sometimes rhythmically contracted and expanded by two lateral muscles, thus forming for a time a kind of pulsating organ.

Chitinous integument of body and furca almost everywhere

covered with minute pits only readily noticeable under a 1/12th in. objective (see figs. 14, 15, 16 and 17). Dorsal surface of most of the thoracic and abdominal segments with lines of excessively minute teeth arranged in various ways characteristic of the different segments, often giving the impression of a series of scales (fig. 17).

Eggs much elongated while in the body, only one or two on either side, forming two lateral lines extending sometimes from the second free thoracic to the last abdominal segment. As no ovisac has yet been observed, it may be that the eggs are deposited upon extrusion and not carried about.*

Length without terminal setae, 1/50th in. to 1/40th in.

Male.—Very similar to female in general appearance, but body divided into ten free segments, the first longest and the seventh to tenth next in length and sub-equal. Posterior margins of abdominal segments armed on ventral surface as follows: 1st, with two widely separated groups of two spines each situated on a slight prominence forming rudimentary sixth feet; 2nd and 3rd, with a row of teeth about half the width of the segment; 4th and 5th, with a row across whole width of segment. Anal plate as in female, also furcal lobes and terminal setae, except that the two little curved rows of teeth on the inner sides of the furca are not so well developed. The edge of the anal plate is toothed in the young stages as in the female.

First antennae modified in the usual way with no very characteristic features. First four pairs of feet almost exactly as in female except that the inner branches of the second, third and fourth pairs are larger and specially modified as follows: 2nd (fig. 20), with a thick slightly curved process (? enlarged spine) projecting downwards from the anterior face of the basal joint and probably forming with the second joint a pincer-like apparatus; 3rd (fig. 21), with second joint carrying two strong terminal setae, one of which is about a third the length of the other and shaped like the blade of a knife, and the first joint bearing a very large trailing spine curved towards the base; 4th (fig. 7), with both joints leaf-like, the second having a curiously twisted little spine on the lower outer margin. Fifth feet (fig. 9) simpler than in female, the slightly extended part of the basal joint with only two short spines, the second joint

* See note on p. 440.

of a more elongated and rectangular shape with a spine arising from near the base on the inner edge, and four spines from the distal edge, the third of which from the inner side turns outwards across the outer spine. None of the spines are of the flattened blunt type present on the fifth foot of the female.

The spermatophore (fig. 19) is flask or retort-shaped with very thick walls, the outlet tube being embedded for a part of its length in a mass of cementing material.*

Length without terminal setae, about 1/50th in.

As regards the habits of *M. arboricola* not very much can be said. They are not very good swimmers, their movements in the open water being best described, perhaps, as an active wriggling assisted by the beating of the feet rather than as true swimming produced chiefly by the action of the feet. On the whole they seem to prefer moving downwards more than upwards when free from support. They can, however, cling very strongly even to glass, and often in this way travel about the sides of the vessel in which they are kept. Very often I have found that they have clung to the inside of the pipette whilst being transferred from a bottle to the live-box. When placed in a watch-glass I have noticed on several occasions that a tap on the glass had the effect of suddenly stopping their movements just as if they were feigning death.

As already mentioned, *M. arboricola* has only been found in little hollows on tree trunks in Epping Forest, and so far only in the Theydon Bois and High Beech districts.† The first specimens were found in 1904 near Theydon Bois, and since that date the species has been obtained many times either actually living in the water and sediment or developing out of the black earthy deposit taken from dry hollows and placed in water. It has happened on several occasions that no trace of the animals could be found in the first instance, but that after several weeks,

* This peculiar mass can be seen in the same relative position while the spermatophore is still within the body of the male. It seems therefore to be a constant character and not merely a temporary feature produced at the time of attachment to the female.

† The fact that so many of the Epping Forest trees have been pollarded in bygone times has had the effect of largely increasing the number of cavities and hollows on their heads and trunks in which water can accumulate in wet weather, thus rendering the district a particularly favourable one for the study of the fauna and flora of such a peculiar environment. The systematic investigation of this fauna and flora is much to be desired, and could scarcely fail to yield valuable results.

or even a month or two, specimens have begun to appear. From the fact that the females have not been observed carrying ovisacs * it seems possible that the eggs are dropped into the sediment to lie dormant for a time, or even to be dried up and so perhaps blown about by the wind. This might account for their distribution from one tree to another, although it is very probable that insects, of which a number of forms occur in the same situations, may also be a means of dispersal. In this connection and also in relation to their peculiar habitat the wonderful vitality of the animals may play an important rôle. They seem capable of living for a very long time in quite small quantities of water and with scarcely any food. On one occasion specimens continued in evidence for four and a half years in a 3-in. × 1-in. glass tube in which the collection had been brought home. The tube contained nothing in the way of food, except the very innutritious-looking original sediment, and nothing was added during the whole time but a little clean water. Individual specimens, too, have been kept for months in very small tubes with only the merest trace of sediment and have remained perfectly active. Such powers of endurance must evidently be of the greatest value to them in their natural surroundings.

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* See note on p. 440.

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Explanation of Plates 24 and 25.

Moraria arboricola sp. nov.

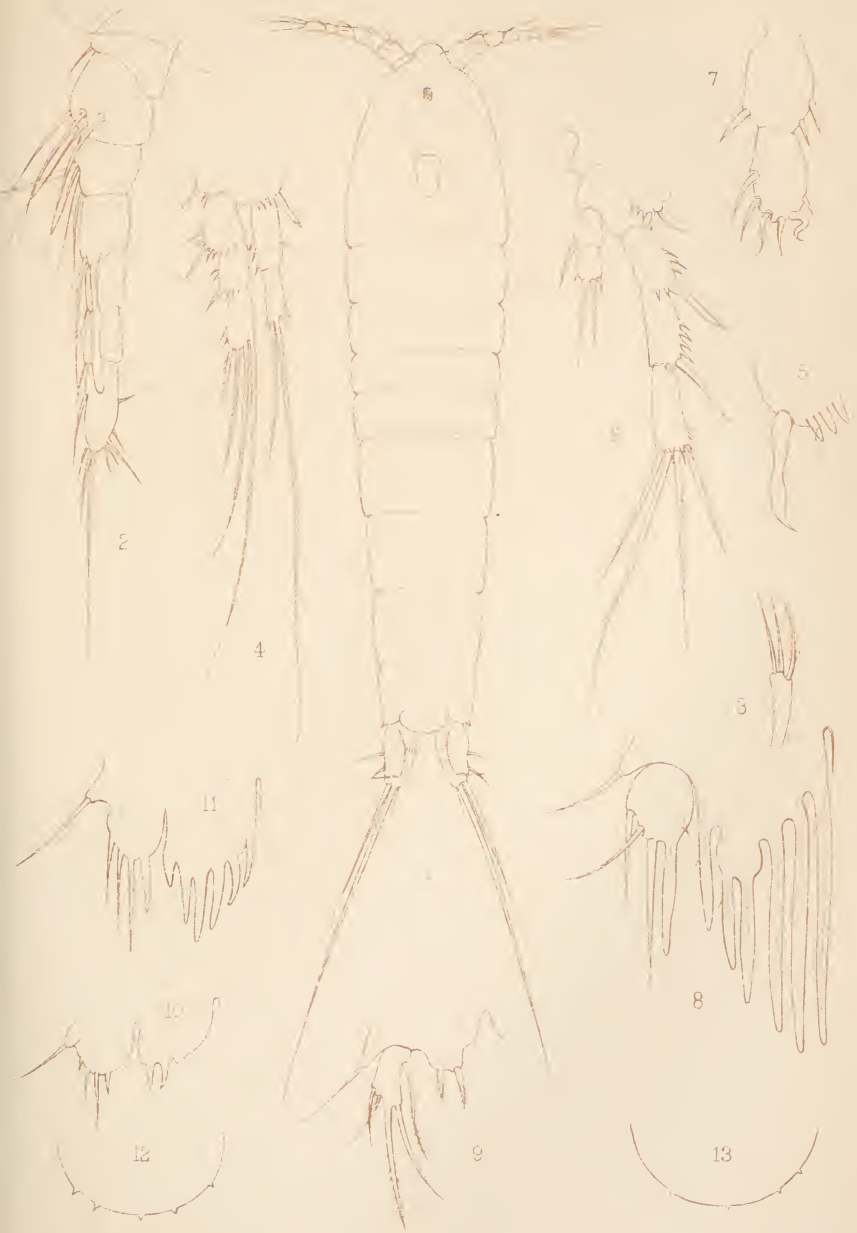
Fig. 1. Dorsal view ♀, × 200.
„ 2. First antenna ♀, × 700.
„ 3. Accessory branch of second antenna

Fig. 4. First foot ♀, × 600.
„ 5. Seta on inner angle of basal joint of first foot ♂.
„ 6. Fourth foot ♀, × 600.
„ 7. Inner branch of fourth foot ♂, × 1000.
„ 8. Fifth foot ♀, × 1000.
„ 9. „ „ ♂, × 700.
„ 10. „ „ young ♀ (antepenultimate stage).
„ 11. „ „ „ ♀ (penultimate stage).
„ 12. Anal plate, young (three stages before adult).
„ 13. „ „ „ (penultimate stage).
„ 14. Last abdominal segment and furca from side ♀, × 700.
„ 15. „ „ „ „ „ dorsal view ♀, × 700.
„ 16. „ 3 „ segments „ „ ventral view ♀ (somewhat flattened and contracted), × 350.
„ 17. First and second abdominal segments, dorsal view ♀, × 350.
„ 18. Receptaculum seminis ♀, × 900.
„ 19. Spermatophore, × 400.
„ 20. Inner branch of second foot ♂ (from left side), × 500.
„ 21. „ „ „ third „ ♂, × 500.

Note added April 1915.

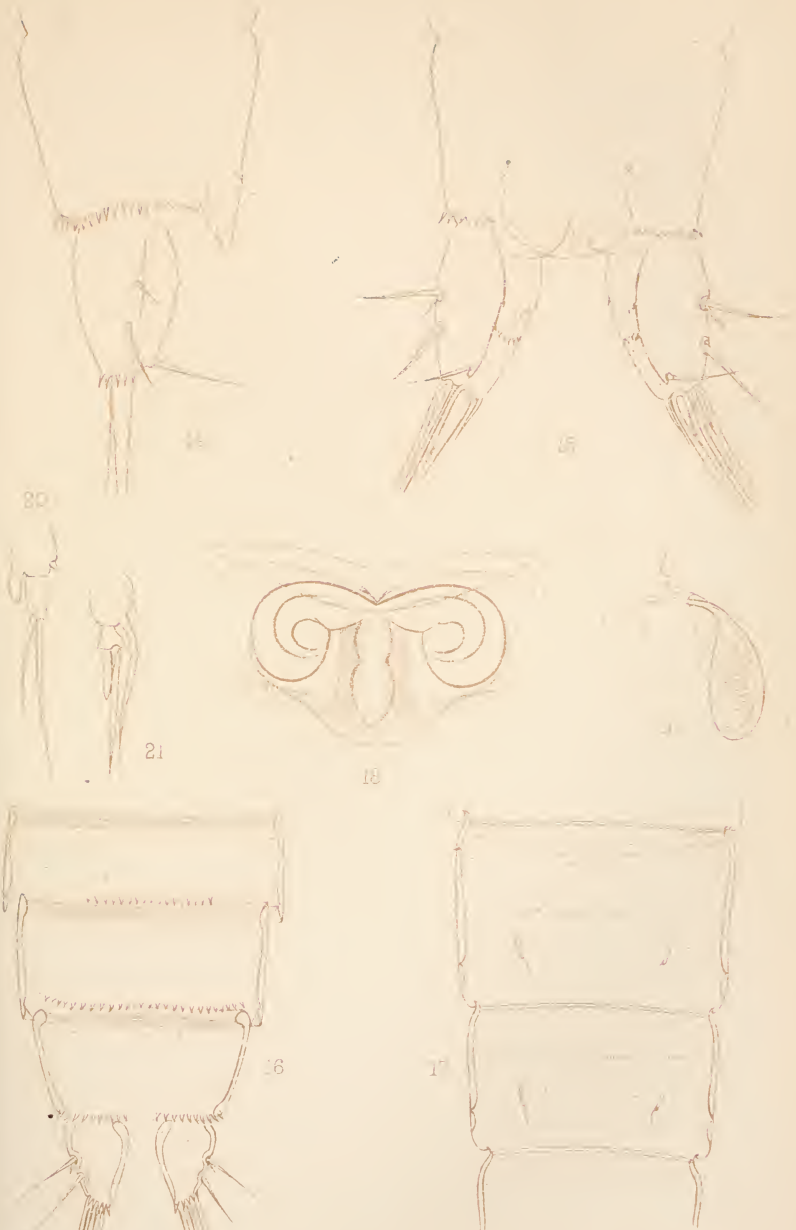
A single individual of *M. arboricola* has now been seen carrying an ovisac containing four eggs, the latter being almost perfect spheres 1/500th inch in diameter. The ovisac itself was very delicate and soon became detached, and also separated into two parts, each containing two eggs, by the movements of the animal when lightly held in the live-box.

Nauplii in various stages have also been seen. The earlier forms exhibit a somewhat elaborate structure on the back, consisting of three pairs of papillae with pointed tips lying between two strong lateral thorns. Whether this is characteristic of the species or not is unknown.



D. J. Scourfield del. ad nat. West, Newman lith.

Morapia arboricola g. n.



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West Newman lith.

Monaria arboricola sp. nov.

SOME DETAILS IN THE ANATOMY OF THE RAT-FLEA, *CERATOPHYLLUS FASCIATUS* Bosc.

By Prof. E. A. Minchin, M.A., Hon. Ph.D., F.R.S.

(*Read January 26th*, 1915.)

Plates 26–32.

During the past five years I have been engaged, in collaboration with a friend, upon investigations, recently published,* into the development of the rat-trypanosome in its invertebrate host the rat-flea (*Ceratophyllus fasciatus*). In the course of this investigation we have dissected and examined some 1,700 fleas; and although these dissections were not undertaken with the primary object of studying the anatomy of the flea, but only with the intention of extracting and examining those organs of the flea likely to contain stages of the trypanosome, it goes without saying that we have not pulled so many fleas to pieces without gaining some insight into the structure of the insect, and it seemed to me worth while to study some anatomical points of structure in more detail and in special preparations. Some parts of the flea are very interesting as regards their structural relations and make very beautiful microscopic preparations which can be mounted with very little trouble. I thought it might interest the members of the Club if I laid before them a brief account of some points of flea-anatomy seen by the way—*obiter visa*, if I may use the expression.

Before describing these observations, I wish it to be clearly understood that this paper does not pretend to give a complete anatomical description either of the flea as a whole or even of the systems of organs that are dealt with. There are many structural details which could only be made out by sections, and I have had no leisure for the task of section-cutting, always a difficult and laborious undertaking in the case of insects, on account of the toughness of the chitinous cuticle, which cannot

* Minchin and Thomson, "The Rat-trypanosome, *Trypanosoma lewisi*, in its Relation to the Rat-flea, *Ceratophyllus fasciatus*." *Quarterly Journal of Microscopical Science*, Vol. LX., Part 4, 1915.

be dissolved out. I do not propose to describe any details here which cannot be verified by an observer possessing a dissecting microscope * and a pair of mounted dissecting needles—and a flea! In fact the results obtained by me and set forth here are based entirely on what may be termed "needlework."

Before proceeding to anatomical descriptions, I may give a brief account of the technique I have employed. The flea at liberty is, I need not say, an active and elusive insect. But when placed on the surface of water, he is perfectly helpless, and floats there without being able to escape and without drowning for at least twenty-four hours, provided there is no soap in the water; if there is a trace of soap the cuticle of the flea is wetted and the insect sinks and is soon drowned. (This hint may be borne in mind as being often useful in the home.)

Having therefore caught your flea, put it on the surface of some water and keep it until you can proceed further with your operations. An expeditious way of catching the flea is to get it to hop straight on to the surface of water. In doing this remember that a flea always hops by preference away from the source of light, never towards it.

When it is desired to dissect the flea it should be gathered off the surface of the water with a fine forceps and placed in a drop of physiological salt-solution (0·75 gramme sodium chloride in 100 cubic centimeters of distilled water) on an ordinary microscopical slide, which is then placed on the stage of the dissecting microscope.

For the dissection I use two fine needles mounted in wooden handles. Each needle after fixing in the handle is ground down further on an ordinary hone. One of them is ground to a fine sharp point, the other to a flat cutting edge. For preparing the flat-edged needle, I first take a penknife and pare the extremity of the wooden handle on both sides so that it is shaped like an ordinary brad-awl. I then rub the needle down on the hone in two planes parallel to the two cuts made in the handle, checking the process under the dissecting microscope and trying to get a rounded cutting edge, not an edge which terminates in a straight line like an ordinary chisel. The object of paring the wooden handle is both to guide the hand when rubbing down the needle

* I have used in all my work a Greenough binocular dissecting microscope made by Zeiss.

on the hone, and also to distinguish the flat-edged needle from the pointed one. When dissecting I use the pointed needle in my left hand for holding the object, and the flat-edged needle in my right hand for cutting. The needles should be pushed far into the wooden handle, so that only a short length is free, otherwise the needle is too springy and is liable to snap under pressure.

The flea was left in the drop of salt-solution, where it is kicking about violently and may succeed, if not watched, in getting out on to the slide and hopping off. It is therefore best to begin by decapitating the flea. This can be done by holding it still with the pointed needle and snipping off the head with the flat-edged needle. The dissection can then be proceeded with in a manner free from haste or anxiety.

I will describe now a method of making permanent preparations of the organs of the flea which I have found very useful. There is not a single detail of anatomy described in this paper which I could not demonstrate to a sceptic in my permanent preparations * at a moment's notice. Let us take the abdominal nervous system, for example. The complete nervous system of the flea consists, as in other insects, of the three sets of nerve-ganglia: (1) the cephalic ganglion-complex, or brain, situated in the head dorsal to the digestive tract (supra-oesophageal); (2) three pairs of thoracic ganglia, corresponding to the three thoracic segments: (3) a chain of abdominal ganglia extending into the abdomen. Parts (2) and (3) are ventral to the digestive tract and constitute a continuous chain of pairs of ganglia, but the two ganglia of any given pair are fused together so as to appear like a single ganglion-mass. Each pair of ganglia is connected with the pair next behind or in front by a pair of stout nerves, known as "connectives," and it can be plainly seen that these connectives remain distinct in each pair, and are not fused together like the ganglion-pairs (Pl. 26). The first pair of thoracic ganglia is connected with the brain by a pair of peri-oesophageal connectives. From the ganglia are given off nerves to the various organs of the body.

It is almost impossible to dissect out the brain, and to study its structure and relations sections would be necessary. It is difficult, but by no means impossible, to dissect out the thoracic ganglia. Major Christophers, I.M.S., who worked for a time in my

* These preparations are now the property of the Club.

laboratory at the Lister Institute, made some beautiful dissections of the ventral nervous system of the flea, showing both thoracic and abdominal ganglia in continuity. On the other hand, it is by no means difficult to dissect out the abdominal chain in its whole length, up to and including the large metathoracic ganglia, the ganglia of the jumping legs. To do this the flea should be held by the thorax with the pointed needle, while with the flat-edged needle the abdominal segments are carefully detached and pulled off from behind forwards successively, until only the thoracic segments are left. If the operation has been successfully performed, and the abdominal segments together with the contained digestive and reproductive organs removed, the abdominal chain of ganglia will be seen proceeding from, and adhering to, the hindmost thoracic segment. With practice the complete severance of the abdomen and its organs from the thorax can be effected with one pull.

Now take another slide and place on it a cover-slip ($\frac{3}{4}$ inch square). Place the slide and cover-slip on the stage of the dissecting microscope, put a quite small drop of salt-solution on the cover-slip, and transfer the thorax of the flea from the slide on which it was dissected to the small drop of fluid on the cover-slip, and there proceed with the dissection. The big metathoracic ganglion-mass can be seen quite plainly in the hindermost part of the thorax, with the abdominal chain of ganglia proceeding from it. With the needles the metathoracic ganglion must be carefully dissected out and set free from the thorax; this operation is not at all difficult, though it requires both skill and practice to dissect out the first two thoracic ganglia as well, in unbroken continuity with the rest of the ganglionic chain. If during the dissection the cover-glass slips about on the slide, it can be fixed quite firmly by letting a tiny drop of distilled water run in between cover-glass and slide, but I avoid this as a rule, because it makes it difficult to get the cover-slip off later on.

When the dissection has been completed, the fragments and debris of the thorax should be removed and cleaned up as much as possible, leaving the nervous system in the small drop of fluid on the cover-slip. Now the cover-slip must be lifted carefully off the slide and all superfluous moisture drained off it, so as to leave the nervous system stranded on the cover-slip, as near the centre as possible. The fluid can be drained off either by tilting the

cover-glass and letting the salt-solution run off, or, if the nervous system shows a tendency to run off with the fluid, by holding the cover-glass flat and carefully mopping up all superfluity of fluid with a small piece of filter-paper. The object to be attained is to leave the specimen stranded on the cover-glass and to drain off as much of the salt-solution as possible, in order that by capillary attraction the object may be pressed against the cover-slip; but on no account must the fluid be allowed to dry completely. When this has been done the cover-slip is inverted, so that the object is on its lower side; and then it is dropped face downwards quite flat on to the surface of some fixative fluid.

Various fixatives can be used, but I have nearly always made use of 5 per cent. sublimate-acetic—that is to say, saturated solution of corrosive sublimate in distilled water, 95 volumes, mixed with glacial acetic acid, 5 volumes. When fixing the preparation some of the fixative is put into a large watch-glass or clock-glass and the cover-glass with the adherent object is dropped on to it and remains floating on the surface of the solution. In nine cases out of ten the object remains firmly adherent to the under side of the cover-glass, if one has hit the happy medium in draining off the fluid in which it was dissected out. If superfluity of the salt-solution remains, the object will come off; if it has been allowed to dry up altogether, the preparation is ruined.

The cover-glass with the adherent organs can now be manipulated just as if it was a smear, lifting the cover-slip with an ordinary forceps and transferring it from one liquid to another. After the preparation has been fixed in the sublimate-acetic for some time, say from 10 minutes to an hour, it can be brought up through successive strengths of alcohol in watch-glasses (10 per cent., 30 per cent., 50 per cent. and 70 per cent.) to 90 per cent. alcohol, in which it should be left for a longer time (preferably over night, or as long as is convenient) in order that the preparation may be well hardened and the corrosive sublimate thoroughly dissolved out. In the stronger alcohols the cover-slip will sink, but it rests on its corners on the rounded bottom of the watch-glass and there is no contact or pressure on the object, which of course is on the under side of the cover-slip. It is now apparent why square cover-slips must be used, since they rest on their corners and can be easily picked up with the forceps;

round cover-slips would be in contact with the watch-glass round their whole edge, and be very troublesome to lift up with the forceps or in any other way.

Sometimes the object comes away loose from the cover-slip in the sublimate-acetic. When this annoying event takes place, put the cover-slip into a watch-glass and cover it with 30 per cent. alcohol; then draw up the object from the sublimate-acetic mixture with a glass pipette of sufficiently wide calibre and place it on the upper surface of the cover-slip in the alcohol. Then lift up the cover-slip carefully with a forceps, taking care the object does not float off the cover-slip to one side or the other, but remains stranded on the cover-slip again. Then drain off the alcohol, invert the cover-slip, and drop it face downwards into 50 per cent. alcohol in another watch-glass. This time the rebellious object always sticks to the cover-slip. In all cases the cover-slips should be handled delicately while in the sublimate-acetic or in the weak alcohols, since a too violent jerk may dislodge them; but I have never known an object to come loose after it has got so far as the 70 per cent. alcohol.

I have described this method in full detail because I have found it extremely useful for making permanent preparations of dissections. In the flea, for example, it is very easy to dissect out and mount in this way the entire male reproductive system, from testes to penis, and so display every detail of it; and since the preparation is adherent to the cover-slip, any powers of the microscope, even immersion lenses, can be focused on to it for study of minute details. The principle of the method is that cellular tissues, having been pressed firmly but gently against the glass by capillary attraction, adhere to the glass by their own stickiness; and when the preparation has been well fixed and hardened, the coagulation of the albumins glues the organs so firmly that they cannot be detached without breaking them. Naturally this does not apply to chitinous organs, which are not wetted by water, and can never be made to stick in this way.

The preparations, after having been fixed and hardened, can be mounted unstained, or can be stained first in any way desired. Unstained preparations are best for showing internal details of the chitinous cuticle or skeleton; stained preparations for showing the cellular structure of the tissues and soft parts; the

one method of preparation supplements the other. For staining an alcoholic stain is preferable, since prolonged soaking in watery stains might produce maceration and cause the object to become detached again from the cover-slip. I have always used Grenacher's alcoholic borax-carmine, in which the objects are stained for about five minutes, and then transferred to acidulated alcohol (0·1 per cent. hydrochloric acid in 70 per cent. alcohol), in order to extract all the carmine stain from the cytoplasm of the cells and leave it only in the nuclei. If the stain be not thoroughly extracted in this way the preparation will be very opaque, and I find it best to leave the objects in the acidulated alcohol for about forty-eight hours, changing the fluid occasionally. I believe this method could be improved upon, and that Mayer's alcoholic paracarmine * would give a more transparent stain, and one more easily extracted. Some of the well-known haematoxylin mixtures would probably also give good results.

The stained or unstained preparations are then finished off by passing them into absolute alcohol, then into oil of cloves or any other of the ordinary clearing reagents, and finally into Canada balsam. The cover-slips can be mounted over well-slides or—preferably, in my opinion—on ordinary slides, with the precaution of supporting the corners of the cover-slip on wax feet or in some other way, in order that the objects may run no risk of being crushed between slide and cover-slip.

I will now proceed to set forth some of my observations on the anatomy of the flea, noting, as a preliminary, that all my statements apply to the common rat-flea, *Ceratophyllus fasciatus*, the only species I have dissected. Other species of flea may perhaps show slight differences in some points.

It is also my pleasant duty, at this point, to express my warm thanks to Miss Mabel Rhodes, artist at the Lister Institute, for kindly executing the drawings of my dissections which accompany this paper. They were all drawn with the camera lucida from the actual preparations.

I. *The Abdominal Nervous System.*

The method of dissecting out the abdominal chain of nerve-ganglia has been described above. It is one of the easiest

* For an account of these stains and how to prepare them see Bolles Lee's well-known *Vade-mecum*.

dissections if one is content to get out only the large metathoracic ganglion-mass, in the thoracic series, and not to worry about the ganglia of the first two thoracic segments, which require very careful dissection.

A remarkable feature of the abdominal nervous system is that it presents very marked differences in the two sexes of the flea. These sexual differences are seen at a glance in the two figures on Pl. 26, which are drawn from two preparations to the same scale by means of a camera lucida. At the upper end of each figure we see the large metathoracic ganglion-mass, and at the lower end the large hindmost or terminal ganglion-complex from which nerves are given off to the genitalia. Between these two larger nerve-centres at the two extremities there is a series of smaller ganglia; and it is easy to see that this series comprises seven ganglia in the male and only six in the female.*

It is seen, then, that the male flea has one pair of ganglia more in its abdominal nervous system than the female. Is this an indication of superiority on the part of the male sex? By no means, rather the contrary! In the embryonic development of insects there are some ten or eleven pairs of abdominal ganglia, and in the ontogenetic development, or in the phylogenetic evolution, of insects the tendency is for these ganglia to be concentrated by fusion which takes place progressively from behind forwards. In some of the Diptera—the tsetse-fly, for example, and I believe in the common house-fly also—the concentration of the nerve-ganglia has reached its maximum possible, since the whole ventral chain is concentrated into one large mass situated in the thorax, a mass which represents the three pairs of thoracic ganglia plus the whole abdominal chain, all telescoped forwards into one large ganglion-complex. In the flea, however, the process of concentration and specialisation has not gone so far, and is seen only at the hindmost end of the

* This curious point was discovered by Major Christophers, in his dissections of fleas made in my laboratory. Previous to his work, I had counted the ganglia of a female flea that I was dissecting, and had noted that there were six small ganglia. Subsequently I made a mounted preparation of the abdominal chain of a male flea, and was surprised to observe seven small ganglia; thinking I had made a mistake in my former observation, I looked up my old notes and altered "six" to "seven," never suspecting the sexual differences which were subsequently shown to exist.

nervous system, in the large terminal ganglion-mass, which represents a fusion of the most posterior ganglia. The difference in the number of the abdominal ganglia in the two sexes of the flea shows, therefore, that in the female the concentration has gone one step farther than in the male, since only six abdominal ganglia remain free in the female, but seven in the male. The nervous system of the female has therefore reached one stage in evolution higher in the female than in the male. Similar differences between the sexes are known to occur also in other insects, especially in the Hymenoptera (the order which includes the bees, ants, and wasps), an order in which the superiority in intelligence and in the social virtues of the female over the male is very marked.

Besides the difference in the number of ganglia, the nervous systems of the male and female flea differ also in the arrangement of the nerve-stems given off from the hindmost ganglion-mass. In the male two stout nerves are given off, which run on either side of the "corkscrew-organ" (see p. 454), and are distributed mainly to the powerful muscles which work the penis. In the female, however, three pairs of moderately stout nerves are given off, which go to the genitalia, but I have not been able to trace their exact distribution.

Comparing the two figures, it is seen that the male and female nervous systems are approximately of the same absolute length. Since, however, the female flea is considerably larger than the male, the nervous system of the female is relatively much the shorter, and does not extend so far into the abdomen as that of the male. Consequently the nervous system of the male is the easier to dissect out.

As regards minuter details, the nerve-ganglia are seen to contain a number of nuclei, representing the ganglion-cells, which have a bilaterally symmetrical arrangement, showing that each ganglion-mass is a fusion of a pair of ganglia. The nerves which come off from the ganglia right and left contain small, elongated nuclei, which are the nuclei of the connective tissue-sheaths of the nerves. The connectives running between the successive abdominal ganglia contain no nuclei, but the stout connectives passing forwards from the metathoracic ganglion-mass contain elongated nuclei similar to those of the peripheral nerves.

II. *The Salivary Glands.*

Having occasion to dissect some flea-larvae, I was struck by the fact that the salivary glands of the larva differ greatly, both in size and in complication of parts, from those of the adult flea. I will begin with the adult, in which the glands are both smaller and simpler in structure.

In the adult flea the salivary glands lie in the abdomen, right and left of the stomach, in the form of two tiny pouches on each side (Pl. 27, B and C). Each pouch consists of large glandular cells, which tend to stain very opaquely and have large nuclei. The two pouches of each side give off each a short duct, and these two ducts unite into a long duct running forwards on the side of the body to the anterior thoracic region, where the two ducts from the two sides of the body unite into a common salivary duct, which runs forwards to open, doubtless, into the hypopharynx, as in other insects. The paired salivary ducts have a very characteristic appearance, being lined by a chitinous cuticle which shows internally a system of rather irregular transverse thickenings. This appearance is seen from the point where the ducts issue from the glands up to a short distance from the spot where the paired ducts unite to form the common salivary duct; the structure of the ducts recalls to some extent that of a tracheal tube, but the transverse thickenings are not so perfectly regular as in the tracheae. At the point of union of the right and left salivary ducts, however, there is a Y-piece in which the duct diminishes in calibre to about half, and has no transverse thickenings. External to the chitinous lining, the duct is covered by a delicate layer of flat epithelium, which does not show distinct cell-outlines, but has the appearance of a plasmodial or syncytial layer of protoplasm with scattered nuclei.

The salivary gland of the adult flea, on account of its small size, is not so easy to dissect out; the glands of the female are slightly larger than those of the male. On the other hand, the salivary glands of the larva, which are plainly visible through the body-wall of the living insect, are very easily dissected out. All that is necessary is to decapitate the larva in such a way as to cut off the first or first two thoracic segments, together with the head, and then to press with the flat of a dissecting needle gently along the body from behind forwards, so as to squeeze out

the contents of the body-cavity through the cut end of the trunk. The salivary glands sometimes come out as soon as the flea is decapitated, without any such pressure, and it is easy to get them on to a cover-slip and fix them.

Almost the only point in which the larval glands (Pl. 27, A) resemble those of the adult is in the characteristic structure of the duct, which can be recognised immediately. Passing back along the duct (d.), we come to a thin-walled dilated sac or reservoir (r.), quite absent in the adult. Behind the duct a tubule begins, composed of lightly staining glandular cells. After a short course this tubule becomes continuous with the gland proper, which is composed of darkly staining glandular cells, and branches out into three lobes or diverticula, two of which run forward (l.a.^{1}, l.a.^{2}) and one backward (l.p.) alongside of the digestive tract. All this arrangement of duct, reservoir, and gland is, of course, duplicated on each side of the body, right and left.

Accompanying the larval salivary gland are two elongated pads or cushions of fat-body, which are very difficult to separate from the gland without damaging the glandular lobes. In the hinder of these pads of fat I found in many fleas a body which looked exceedingly like a parasitic cyst, for which I mistook it at first. Specimens mounted whole showed the "cyst" to be composed of large cells in the interior, showing a tendency in the more advanced specimens to arrangement in longitudinal rows, and enveloped by a layer of flat epithelium at the surface. At its hinder end the "cyst" is prolonged into a delicate cord of cells which could be traced in some specimens a long way back. Further investigation showed, however, that when this "cyst" was present on one side of the body it was also present on the other side in exactly the same degree of development; and further, that when the "cysts" were absent in the fat-body on the level of the salivary glands, they were to be found in other pads of fat-body situated farther back, on the level of the intestine right and left. Hence it was obvious that the supposed parasitic cysts were simply the genital rudiments, situated farther forward in the larvae of one sex than in the other. Whether it is the male, or the female, in which they are situated farther forward, I cannot say.

The striking differences between the larval and adult flea in

respect to the salivary glands must be related to the difference in their habits. The adult flea, I need not say, is a blood-sucker, and in blood-sucking insects generally the function of the salivary glands is believed to be that of producing a secretion which is mixed with the ingested blood and prevents it from coagulating. Incidentally the salivary glands of the adult flea, if crushed and examined, can be seen to contain many yeast-like bodies of several kinds, and it is supposed that it is these microbes which are responsible for the local irritation and itching caused by the puncture of the flea's proboscis. The flea-larva, on the other hand, is more or less omnivorous, but appears to feed principally on the faeces of the rat, as well as dirt and debris of all kinds. Consequently its salivary glands have a function in the insect's economy entirely different from that of the adult flea, assisting probably in the digestion of the food, and their larger size in the larva indicates a greater secretive activity than in the adult.

III. *The Male Reproductive Organs.*

The genitalia of the male flea exhibit a singular complication of parts and of their arrangement, but are nevertheless very easy to dissect out, and with a little care the entire reproductive system, from testes to penis, can be mounted as one preparation, in which every detail can be studied with the exception of those minuter points of structure which require sections for exact study.

A general sketch of the various parts is given in Plate 28. All the details of this sketch have been drawn from mounted dissections with the camera lucida at a magnification of 150 diameters, reduced in the reproduction by one-half. At the same time the relation of the various parts and their relative position in the body has been checked by sketches of the whole system, both of such parts of it as can be seen through the body-wall of the flea without dissection, and also as it is seen when the abdomen of the flea is freshly opened with the least possible disturbance of the organs.

Most anteriorly are situated the two conspicuous testes (T, T.) with their ducts coming off from them, and shaped somewhat like a pear would be if the stalk (the duct) came off from its thicker end. The testes lie dorsal to the stomach, but vary to some extent both in size and arrangement. When the testes are of large size, as in the younger males, they lie one in front of the

other, and then the duct of the testis lying more anteriorly runs straight back, while that of the testis situated more posteriorly is coiled. When the testes are smaller, as in the older, more exhausted males, they lie side by side and their ducts run straight back.

When the testis is examined it is seen at once to consist of two parts, a dilated bladder-like portion of ovoid shape, at the base of which is a coiled tubular portion. The bladder-like portion appears to be the testis proper (T), while the coiled tubular portion (ep.[1]) recalls the structure in the human testis known as the epididymis, and may be known conveniently by this designation. In one of my dissections I succeeded in uncoiling the epididymis forcibly, by pulling on the duct (ep.[2]). It was then seen that the epididymis is a thin-walled tube, filled with ripe spermatozoa ; consequently, from the point of view of function, the epididymis represents a vesicula seminalis, that is to say a receptacle for the storage of ripe sperm.*

The calibre of the tubular epididymis narrows rapidly as it passes on into the duct, which may be called here, as in other animals, the vas deferens. The right and left vasa deferentia (v.d.[1], v.d.[2]) run back a little way and join to form the common vas deferens (v.d.[3]), but it can be seen very easily that the union of the paired vasa deferentia is merely external and not internal, since the lumina, or internal cavities, of the two ducts remain quite distinct.

The common vas deferens runs to a set of glandular structures which I regard as corresponding to a prostate gland, and consisting altogether of four blind tubular diverticula ; a median pair of short tubules, which may be termed the median prostates (r.m.p.), and a much longer pair of lateral tubules, which may be called the lateral prostates (r.l.p.). The two median prostates are in close contact, but their cavities are quite distinct and independent. The walls of the tubules are composed of a single layer of glandular epithelial cells of small size, which show in surface view very distinct polygonal outlines (Pl. 30, B). The tubules contain

* The structure of the testis was not quite correctly described in our monograph on the development of *T. lewisi* (Minchin and Thomson, *l.c.*). When that was written I had not seen the epididymis uncoiled, and regarded the dilated bladder-like portion of the testis as a vesicula seminalis.

a cavity, relatively spacious, in which I have never seen any spermatozoa; they cannot therefore be regarded as vesiculae seminales, but probably have a purely secretive function.

The common vas deferens runs towards the median prostates and then loops round them in a peculiar manner, running in the valley between the two contiguous median prostates. Just after the two still separate ducts, which form by their apposition the common vas deferens, have passed the prostates, there is a slight dilatation of the ducts into which the prostatic tubules open, but quite separately; that is to say, the left median and left lateral prostate open into the left half, the right median and right lateral prostate into the right half, of the common vas deferens.

The common vas deferens, after receiving the openings of the prostates, runs on towards the penis as a duct which may be termed, as in other animals, the ductus ejaculatorius (d.ej.). Like the common vas deferens, however, the ductus ejaculatorius is a double-barrelled structure, consisting of two ducts in close contiguity, but with distinct internal cavities.

At the point where the ductus ejaculatorius enters the penis there is a most singular complication of structure. The proximal end of the penis is prolonged into a spirally coiled organ which, for lack of a better name,* I propose to call the "corkscrew-organ," since it resembles in form a corkscrew, or a spiral drill or borer, of about four turns (c.s.o.). The ductus ejaculatorius runs straight to the base of the corkscrew and through its axis; at the point where it enters the axis of the corkscrew the ductus ejaculatorius can be seen very plainly to be still double; it is difficult to make out clearly what happens in the axis of the corkscrew, but when this structure is viewed from the top, it is seen equally plainly that the duct emerges from the axis as a single duct, no longer double-barrelled. It is evident, therefore, that the two ducts that come from the testes, maintaining their individuality and distinctness up to this point, become confluent at some spot in the axis of the screw. This single duct, the duct

* I regret to say that my meagre acquaintance, which I have not had the leisure to extend, with the vast and scattered literature relating to the anatomical structure of insects, is inadequate to permit me to state whether this or similar organs in other insects have been studied in detail and whether there exists already a special technical term for the structure which I term here in a purely descriptive manner "corkscrew-organ."

which runs the whole length of the penis, may be called distinctively the urethral duct (d.).* The exact point at which it begins in the axis requires to be determined by sections.

The urethral duct emerges from the axis of the corkscrew at its apex and there turns and runs outwards round the outer edge of the spiral of the corkscrew, enclosed between two chitinised bars, or more correctly thickenings of the wall of the duct. These chitinous thickenings are best seen in unstained preparations of the penis (Pl. 29). The chitin on the inner side of the duct (*i.e.* on the side of it turned towards the axis of the spiral) is the thicker and stronger of the two, but is only continued from the base over about three turns of the spiral, while the thinner chitinous bar on the outer side of the duct is continued for nearly a whole turn more.

The structure of the corkscrew-organ is difficult to make out in full detail without sections, but if a portion of the spiral be carefully examined, the following points can be seen in dissections of the whole apparatus stained and mounted (Pl. 30, A). At the extreme outer edge of the spiral is seen the narrow urethral duct (d.) with its chitinous thickenings on the inner and outer side. Running from the axial region, which can also be seen in the unstained preparations to have a chitinous support (ax.), is a superficial layer of radiating striated muscles, which run across from the axis centrally to the duct peripherally; this layer can be focused without difficulty. At a deeper focus, below the radiating muscles, two structures can be made out lying between the axis and the duct; close to the axis and apparently attached to it, is a spiral muscle (sp.m.) composed also of striated muscular fibres; and between the spiral muscle and the urethral duct is a cushion of cells which appear to be glandular in appearance, but sections would be necessary to determine their precise histological nature. These various structures can be seen best in the lowest coil of the corkscrew; they are depicted in Plate 30, A, but it is difficult to

* If a dissection of the male reproductive organs be treated with caustic potash, everything up to the base of the corkscrew, that is to say the vasa deferentia, prostates and ductus ejaculatorius, dissolve away, but the urethral duct issuing from the apex of the corkscrew remains very distinct and this is, as a matter of fact, the best way to study its course. It would appear, therefore, as if the urethral duct is distinguished from the other ducts by the possession of a chitinous lining, and therefore represents, probably, an ingrowth of the outer integument in origin.

combine clearly in one sketch things seen in the microscopic preparation at different foci.

Seen in life, that is to say in a freshly dissected flea, the corkscrew-organ is usually performing peculiar pulsating movements, which remind one to some extent of the movements of the hairspring of a watch, with the difference that the hairspring lies in one plane, while in the organ of the flea the axis of the spiral is prolonged vertically so that a form like a corkscrew results. It is seen that in the living condition the corkscrew becomes alternately first longer and narrower and then shorter and broader. The elongation and narrowing of the corkscrew is doubtless brought about by the contraction of the radiating superficial muscles; these in their turn are antagonised by the spiral muscle, which by its contraction would tend naturally to make the corkscrew shorter and broader.

As to the function of corkscrew-organ, I can only offer the suggestion that it may act as a sort of sperm-pump. The movements seen in the freshly dissected flea may perhaps become more active and regularly rhythmical during the act of copulation, and serve to pump the sperm on from the ductus ejaculatorius and vasa deferentia into the penis. This is, of course, a mere conjecture from the observed facts of its structure and activity. If, on the other hand, the cushion of cells between the spiral muscle and the duct be glandular in nature, the organ as a whole must have other functions in addition to that of acting as a pump.

The penis is an organ of complicated structure, which I will deal with briefly; Pl. 29 shows what I have been able to make out in preparations mounted unstained, or further cleared with potash before mounting. The penis (P.), which is very large in proportion to the size of the insect, is made up of strong thick bars of chitin. It is worked mainly by strong protractor and retractor muscles attached to a broad bar of chitin (b^1), which is a prolongation of the dorsal integument at the right and left margins of the pygidium. The median retractor muscles (m.r.) are attached distally to a prolongation of the dorsal side of the penis, and the lateral retractors (l.r.m.) are attached to a bar (b^2) which arises from the ventral side of the penis; there are two such bars, right and left, diverging from one another like a V; it is clearly impossible that the penis could be protruded farther from

the body than the point of insertion of these bars (b^2). I think it probable that there are more muscles attached to b^2 than are seen in my figure, but have become torn away in the dissection. Both b^1 and b^2 can be seen clearly through the body-wall in the uninjured flea. From the thick beam of chitin which forms the dorsal part of the penis a lateral muscle (l.m.) comes off, which is probably attached distally to the integument.

In one of my preparations treated with potash, spermatozoa could be seen very plainly in the interior of the urethral duct, and they have been put into the figure on Pl. 29 in order to show the course of the duct. The spermatozoa (sp.z.) begin in the lowest coil of the corkscrew-organ, where they show a peculiar festoon-like arrangement. As the duct passes into the body of the penis, the spermatozoa take on an arrangement in wavy bundles and the calibre of the duct widens considerably, and at the same time the spermatozoa show that the duct crosses over the chitinous bar which forms the inner boundary of the duct in the corkscrew-organ, and which has now become very much thinner and more delicate, passing on to be merged into a much thicker bar on the ventral side of the penis. Just a little in front of the middle region of the penis the spermatozoa are heaped up in a way that shows the duct to have become greatly enlarged in calibre, but behind this point the spermatozoa disappear altogether. In stained preparations it can be seen that the penis has a superficial layer of muscles which appear to have a criss-cross arrangement, and lie on the wall of the widened spermatic duct, but they have not been put into the drawing, as their exact position and arrangement are difficult to make out clearly. The contraction of the superficial muscles would doubtless have the effect of contracting the lumen of the penis and ejecting the sperm.

Such are the main points of the structure of this very comlicated apparatus, so far as I have been able to make them out; but I think it probable that there are more minutiae to be described, especially with regard to the structural details of the penis and "corkscrew-organ."

IV. *The Female Reproductive System.*

As regards the primary sexual organs of the female sex, they are of the usual insectan type, and can be dealt with briefly.

There is a pair of ovaries, lying symmetrically right and left in the abdomen dorsal to the stomach. Each ovary consists of a number of ovarian tubes or ovarioles; usually four on each side, but in one of my mounted preparations there are five ovarioles in each ovary. The ovarioles are of the simplest type, composed of successive egg-chambers, increasing progressively in size, without special yolk-chambers. The ovarioles of each side unite into a short paired oviduct, and the paired oviducts of the two sides unite into a median unpaired oviduct, in which, probably, the ovum is fertilised and subsequently becomes invested by a shell.

In addition to the ovaries and oviducts, which are very easy to dissect out, there lies, ventral to the rectum, an organ found in all fertile female insects, the receptaculum seminis, into which the sperm is received at copulation and stored up in order to fertilise the eggs as required. The receptaculum and its duct are by no means difficult to dissect out and mount, and make a singularly beautiful and fascinating microscopic preparation (Pl. 31). The duct is coiled up into a veritable labyrinth, and the sole difficulty in the dissection is to uncoil it without breaking it.

The receptaculum itself (R.S.) is a chitinous capsule with a brown, delicately sculptured, semi-transparent wall, and a peculiar form. The main portion of the capsule, that portion from which the duct arises, is roughly spherical in form. At one point, which is distant from the origin of the duct by about one-third of the circumference of the main chamber, an outgrowth or diverticulum arises, forming a second chamber, which is horn-shaped, and bends round the main chamber. The horn-shaped chamber is connected, on its concave side, to the main chamber by a sheet of striated muscle (m.r.s.). The contraction of these muscle-fibres must clearly have the effect of approximating the horn-shaped chamber to the main chamber, and at the point where the horn-shaped chamber arises from the main chamber there is a rim of chitin which appears to be softer than the rest of the wall, forming a weaker spot which apparently serves as a hinge, allowing the horn-shaped chamber to be moved slightly; it is at this spot that artificial deformations of the wall of the capsule are often caused as the result of slight shrinkage when the receptaculum is mounted in Canada balsam. The receptaculum is usually packed with spermatozoa, which can be seen through the wall of the capsule, but better still if the capsule be burst

open by pressure under a cover-glass when freshly dissected out. In one of my specimens the receptaculum is empty and contains no spermatozoa; this specimen is also the only one I have succeeded in mounting in Canada balsam without any shrinkage taking place in the hinge-region. This virgin receptaculum also shows some structures in the interior, the nature of which I have not been able to make out clearly, but which look rather like prolongations of the duct into the interior of the main chamber. Sections would be necessary, however, to determine the nature of these internal arrangements, which are not visible in any of my specimens that are filled with spermatozoa.

The duct of the receptaculum (d., d., d.) is of extraordinary length, and just where it arises from the main chamber it is surrounded by a cushion of deeply staining, closely packed cells of glandular appearance (gl.c.), each shaped somewhat like an Indian club. The duct itself has an internal chitinous lining secreted by an external epithelial layer, which is shallow and contains small nuclei in great number but shows no distinct cell-outlines. At its proximal end, immediately after it comes through the glandular cushion already mentioned, the duct is surrounded by a great number of rounded cells (gl.), which have clear, lightly staining contents, and present also a glandular appearance. The rounded cells are thickly clustered round the proximal end of the duct, but as the duct is followed along in a distal direction they diminish in number and gradually thin out until, about half-way along the duct, they disappear altogether, and the distal half of the duct consists only of the chitinous lining and the epithelium with small nuclei.

As the duct approaches its termination it shows some peculiar complications, forming what I propose to call the terminal organ (T.O.). First of all there is a feeble imitation of the corkscrew-organ in the shape of a broad expanded plate, apparently chitinous, on one side of the duct, which performs a spiral twist of one complete turn. The spiral portion passes on into a short length of the duct, which has on one side a thickening of the chitin to form a strong bar (c.b.), bent like a bow, which is strung, so to speak, by a strong muscle of four or five fibres (m.t.o.). I have not been able to determine exactly by dissection where the duct finally opens, whether into the unpaired oviduct or into a terminal genital vestibule or vulva; sections, or

perhaps specimens cleared in potash, would be necessary to determine this point.

The spermatozoa live a very long time, as is well known, in the receptaculum, and are used up gradually to fertilise the eggs as they are laid. In the queen-bee it is known that the insect lays fertile eggs for at least three years, and in some other insects this length of time may be exceeded by a considerable amount. The muscles seen in connection with the receptaculum and its duct may be connected with the function of passing out the spermatozoa. A contraction of the muscle connecting the horn-shaped chamber of the receptaculum with the main chamber would probably force some spermatozoa out into the duct. On the other hand, a contraction of the "bowstring" muscle of the terminal organ would bend the "bow," and so occlude the duct, preventing anything from passing out. There does not seem to be any apparatus for forcing the spermatozoa up the duct and into the receptaculum, but this is effected probably during copulation by the male intromittent organ—possibly by the problematic "corkscrew-organ." The spermatozoa in the receptaculum must be kept alive a long time, and may be nourished by the secretion of the glandular cushion round the origin of the duct, while the rounded gland-cells on the duct may perform some similar function for the spermatozoa during their passage down the labyrinthine duct, the great length of which is difficult to explain in a plausible manner. All these suggestions have, however, only the value of more or less probable surmises.

In the tsetse-fly the receptaculum is a paired organ, and in the gnat there are three receptacula, one median and two paired. In that of the flea there is no sign of any double structure.

V. *Muscle-cells of Stellate Form in the Oesophagus of the Flea.*

In some of our smear-preparations of teased flea-stomachs, made in the course of our investigation into the development of *Trypanosoma lewisi*, there were to be found occasionally specimens of the flea's oesophagus, which adhered to the cover-glass after it had been fixed with Maier's sublimate-alcohol mixture and stained by Heidenhain's iron-haematoxylin method. In such preparations it is easily seen that the oesophagus has a beautiful

and very delicate layer of muscular tissue, in the form of a network (Pl. 32, A, B and C). The individual muscle-cells are branched like ganglion-cells, and their processes anastomose to form the network. Some nodes of the network are formed merely by the union of two or three such processes, while other nodes are formed by the body of the cell, and contain the cytoplasmic cell-body with a nucleus. The processes themselves are transversely striated, and form the actual muscle-fibres. It can be seen that at a cellular node of the network the striated fibres pass right through the body of the cell and come out on the other side, their striation and individuality becoming slightly less distinct in their passage through the cytoplasm of the cell.

Remembering that I had seen muscle-cells of a somewhat similar type in the "crop" or "sucking stomach" of the tsetse-fly, an organ which is morphologically a diverticulum of the oesophagus, I made a preparation of the crop of a common house-fly and found a musculature of a very similar type (Pl. 32, D, E). The main differences are, first, that the cells are on a much larger scale of size, requiring lower powers of the microscope for their study; secondly, that the muscular network has a definitely rectangular arrangement, those fibres which run in certain directions being considerably thickened, and connected with one another by delicate fibres running across at right angles. In some parts the thickening of these longitudinal fibres is much more marked than in others. All the fibres, even the thinnest, show the characteristic transverse striation very distinctly.

The resemblance of the muscular network in the two cases raises some interesting points of phylogeny. In the first place, it should be noted that a contractile network is the most efficient arrangement for the contraction of a bladder, since it gives an even contraction in all directions. The muscles of the human urinary bladder are also arranged in a network, but on a much larger scale than those described here, since the strands of the network are not outgrowths of individual cells, but are made up of thick bundles of contractile cells. It is therefore not surprising to find a network in the contractile elements of an organ such as the crop of the house-fly. On the other hand, it is rather remarkable to find it in the oesophagus of the flea.

Entomologists are generally agreed in regarding the fleas as modified and specialised Diptera—that is to say, as descended from fly-ancestors. If so, they may have once possessed a crop such as is found in the fly, but which, with reduction in the size of the body, has gradually disappeared, and has ceased to be developed. Since, as has been pointed out, the crop is formed as a diverticulum of the oesophagus, the existence of such an organ in the ancestors of fleas might explain the persistence of a musculature of this peculiar type in the oesophagus of the flea. But it would be necessary to examine the oesophageal musculature of other insects before adopting this theory as an explanation of the presence of stellate muscle-cells in the flea.

DESCRIPTION OF PLATES.

Plate 26.

Abdominal Nervous Systems of the Male (left) and Female (right) Flea, magnified 90 Diameters.

th.^{3}, metathoracic ganglion; abd.^{1}, abd.^{3}, abd.^{5}, and abd.^{6}, first, third, fifth, and sixth abdominal ganglia; abd.^{7}, 7th abdominal ganglion, present in the male, wanting in the female; T.g., terminal ganglion-complex. Note the difference in the size and number of the nerves that arise from T.g. in each case.

Plate 27.

Salivary Glands of the Larval and Adult Flea.

A, salivary gland of the larva, magnified 60 linear; d., duct, showing at its distal extremity (to the right) the union with the corresponding duct from the other side of the body; a small portion of the duct is seen magnified 400 linear; r., reservoir; l.a.^{1} and l.a.^{2}, the two anterior lobes of the gland; l.p., the posterior lobe.

B and C, the salivary glands of the adult flea, at B magnified 60 diameters, for comparison with A, at C magnified 160; d., duct; gl., the two pouch-like glands.

Plate 28.

General View of the Reproductive Apparatus of the Male Rat-flea, seen from the Right Side.

T, T, the two testes; ep.^{1}, the left epididymis in its natural coil; ep.^{2}, the right epididymis forcibly uncoiled; v.d.^{1}, v.d.^{2}, the left and right paired vasa deferentia; v.d.^{3}, the common vas deferens; r.l.p., the right lateral prostate gland; r.m.p., the right median prostate; d.ej., the ductus ejaculatorius; c.s.o., the "corkscrew-organ"; d., the urethral duct running spirally round the corkscrew-organ; P, the penis. × 75 linear.

Plate 29.

Chitinous Skeleton and Principal Muscles of the Penis and Corkscrew-organ of the Male Rat-flea, from the Left Side.

P, penis; e.p., external plates of the posterior end of the body; b.^{1}, chitinous bar, an outgrowth of the dorsal integument; b.^{2}, chitinous bar arising from the ventral-posterior end of the penis; l.r.m., lateral retractor muscles running from b.^{1} to b.^{2}; m.r.m., median retractor muscle running from b.^{1} to an outgrowth of the dorsal side of the penis; l.m., lateral muscle running from the side of the penis to the body-wall; p.m., protractor muscle, running from b.^{1} to the penis; c.s.o., corkscrew-organ; ax., its axial skeleton; d., the urethral duct; sp.z., sp z., spermatozoa in the duct, indicating its course where the corkscrew-organ passes into the penis. × 150 linear.

Plate 30.

Details of the Male Reproductive System more highly magnified.

A, a portion of one of the coils of the "corkscrew-organ," seen from the lower surface; d., the urethral duct, running at the extreme outer edge of the spiral; ax., the chitinised axis of the spiral; running from ax. to d. are the superficial radiating muscles, clearly seen; below the radiating muscles two structures are

seen, less clearly; close to ax. is a spiral muscle, sp.m.; between sp.m. and d. is a cushion of cells with nuclei, apparently glandular in nature. × 350.

B, a portion of one of the prostatic tubules, in surface view, showing an epithelium composed of glandular cells with very distinct polygonal outlines. × 350.

Plate 31.

Accessory Reproductive Apparatus of the Female Rat-flea.

R.S., receptaculum seminis; m.r.s., muscles connecting the main chamber of the receptaculum with its horn-shaped prolongation; gl.c., cushion of gland-cells surrounding the duct at the point where it issues from the receptaculum; d., d., d., the long coiled duct of the receptaculum, seen here forcibly uncoiled; gl., gland-cells, thickly crowded on the proximal part of the duct; T.O., terminal organ; c.b., bar of thickened chitin on the wall of the termination of the duct; m.t.o., "bowstring" muscle of the terminal organ. The apparatus is seen at a magnification of 200 linear; at A and B are seen portions of the duct magnified 400 linear.

Plate 32.

Stellate Muscle-cells of the Oesophagus of the Flea and the Crop of the House-fly.

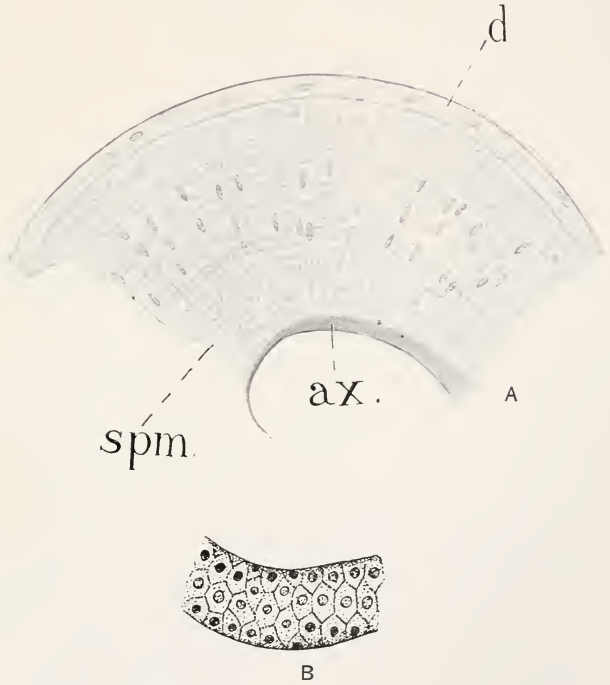
A, oesophagus of the flea, magnified $\frac{1000}{3}$ linear, showing the muscular network; B, a detail of A, magnified 1,000; C, a detail from another specimen, magnified 1,000, showing how the striated muscle-fibres are continued through the cytoplasm of the muscle-cells.

D and E, muscular network from two different regions of the crop of the house-fly; both from the same specimen, and magnified to the same degree as A.

Lister Institute,
January 25th, 1915.

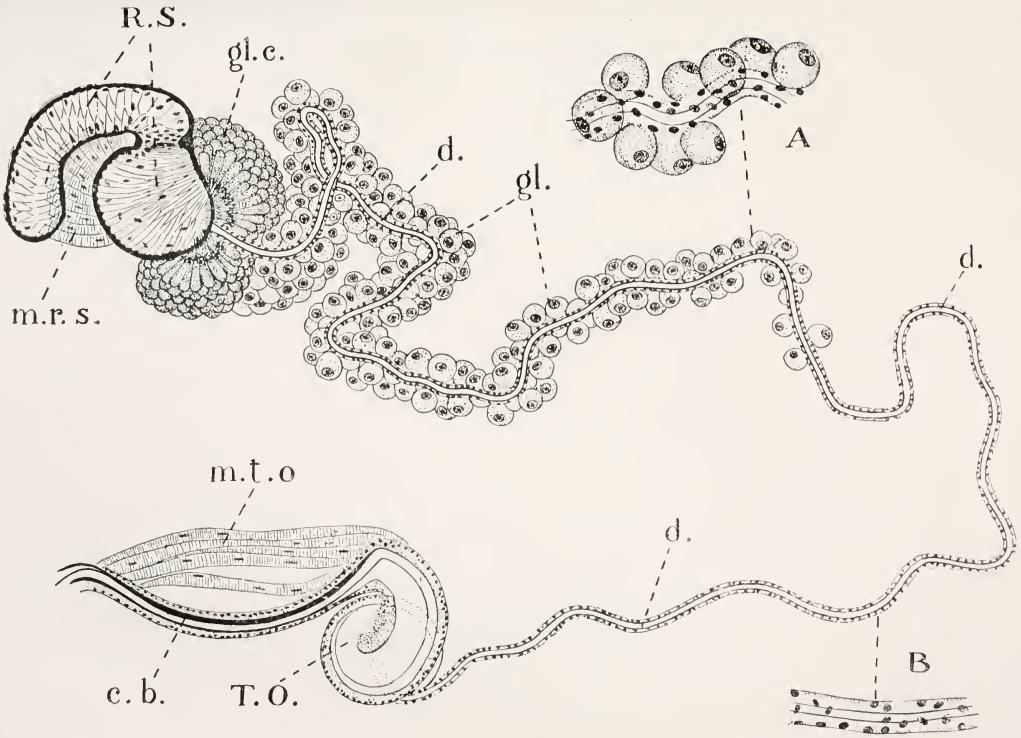
Mabel Rhodes, *del. ad nat.*

Anatomy of the Rat-flea.



Mabel Rhodes, *del. ad nat.*

Anatomy of the Rat-flea.



Mabel Rhodes, *del. ad nat.*

Anatomy of the Rat-flea.

A

B

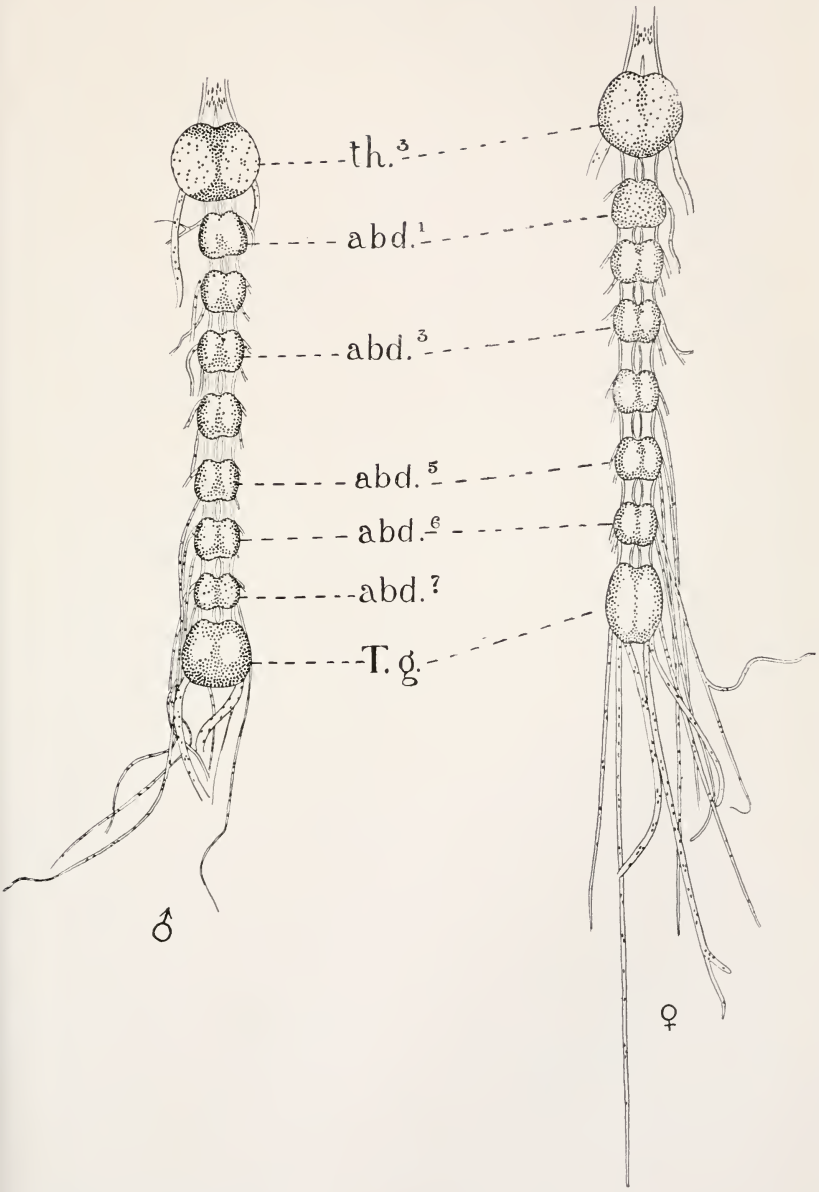
C

D

E

Mabel Rhodes, *del. ad nat.*

Anatomy of the Rat-flea.



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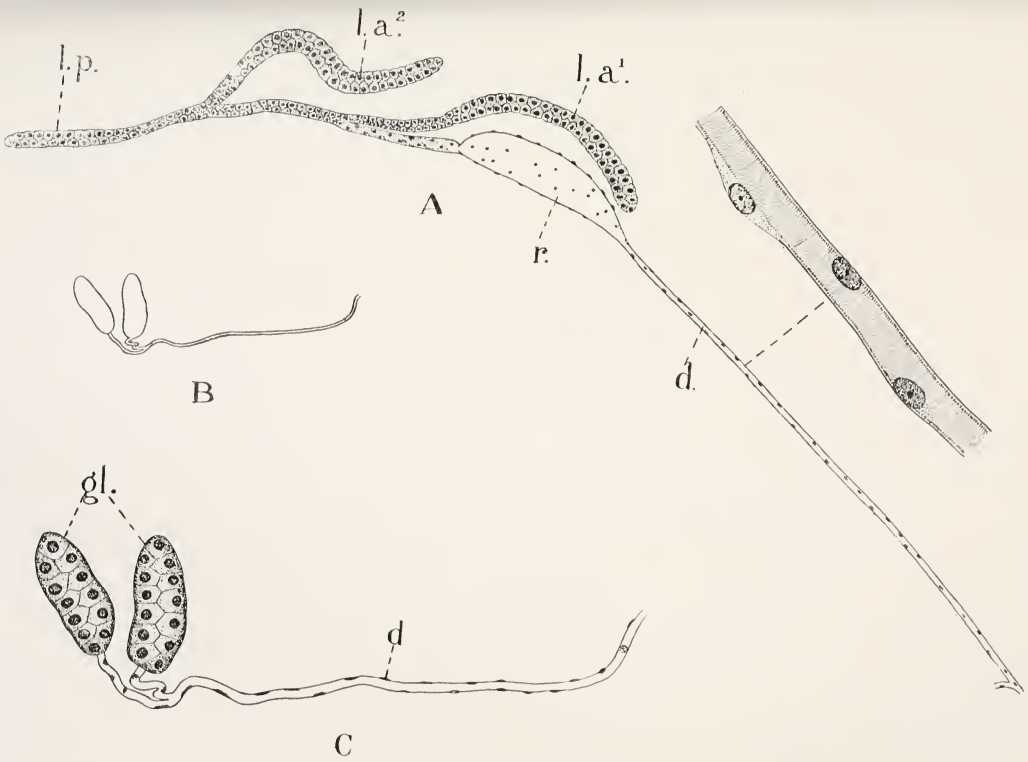

Mabel Rhodes, *del. ad nat.*

Anatomy of the Rat-flea.

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Anatomy of the Rat-flea.

THE PRESIDENT'S ADDRESS.

THE BIOLOGICAL CONCEPTION OF INDIVIDUALITY.

By Prof. Arthur Dendy, D.Sc., F.R.S.

(*Delivered February 23rd*, 1915.)

I need hardly remind you that the organic world, as we know it to-day, is divided by systematic biologists, largely for their own convenience and in accordance with their own particular ideas, into some millions of different kinds or species of plants and animals, and that each of these so-called species consists, usually at any rate, of millions of units which we call individuals.

In making this statement we most of us probably think that, whatever may be our doubts as regards species, we know very well what we mean by the term "individual"; we can recognise and define an individual man or dog, or an individual oak tree or cabbage, at any rate to our own satisfaction. If, however, we carry our investigations a little below the surface of things we soon meet with cases that are not a little puzzling, and my purpose this evening is to inquire, albeit very briefly, whether it is really possible to frame a definition of individuality from the biological standpoint that will be of general applicability throughout the animal and vegetable kingdoms; whether we are really much better off in this respect in dealing with individuals than we are in dealing with species.

There appear to me to be two main paths by which we can approach our problem, the morphological and the physiological. On the one hand we can inquire what constitutes a perfect individual from the point of view of structure, and, on the other, what constitutes such an individual from the point of view of function. In the case of the higher animals we might approach the question in a third way and inquire what constitutes an individual from the psychological standpoint. We shall find, as we pursue our investigations, that each path is beset with difficulties, and that each leads to some very curious situations. We shall also discover that the three paths are not entirely

distinct, but frequently run together, and that the best going is sometimes to be found along one and sometimes along another.

Starting along the morphological road we shall very soon find that there are many grades or orders of individuality, and that what constitutes a perfect individual in one case may by no means do so in another.

Amongst the lower forms of life the individual frequently consists, as you know, of a single cell, a single nucleated mass of protoplasm capable of performing by itself all those actions or functions which are necessary for the maintenance of life. The cell is, of course, frequently looked upon as the lowest structural unit, and the unicellular plants and animals as individuals of the first order. It may fairly be questioned whether this view is strictly correct, for the nucleated cell has already progressed a long way along the path of evolution, and it is quite conceivable that it may have originated as a colony of individuals of a still lower order—micellae, plastidules, biophors, or whatever else we like to call them ; while it is certain that some existing organisms, such as the Bacteria, have not yet attained the level of perfect cells.

We know, however, that all the higher organisms actually start life as single nucleated cells, formed usually by the union of two gametes or germ cells, and that these germ cells themselves originate as complete nucleated cells by the process of cell-division, and not, so far as we can tell, by the multiplication and addition of units of a lower order. This fundamental fact seems to justify us in looking upon the cell as the lowest morphological unit, and we may accordingly accept it as the starting-point for our inquiry.

A unicellular organism, after attaining a certain size, and under favourable circumstances, may divide into two parts which completely separate from one another and form two new and independent individuals. In this simple process of reproduction the parent cell ceases to exist as an individual, but we cannot say that it perishes, for its substance is merely divided between the two daughter cells and there is nothing left over to die.

In the multicellular animals and plants we meet with a very different state of things. Here the individual is composed, not of a single cell, but of a number of such cells, often amounting to very many millions, all united together in one body. Moreover, these cells are not all alike, but very variously differentiated

amongst themselves for the fulfilment of different functions, and all co-operate in a common life which is fuller and more varied in accordance with the greater complexity of structure. This differentiation and division of labour amongst the constituent cells of the multicellular body has undoubtedly been one of the chief means by which progressive evolution has been rendered possible. From the point of view of the individual, however, it has its drawbacks. Each cell is no longer self-sufficing, it can no longer perform by itself all the functions necessary for continued existence. A muscle cell, for example, is dependent upon the blood for its supply of food and oxygen, upon the nervous system for its means of communication with other parts of the body, and upon the skin for its protection. It can do its own particular job remarkably well, but only by sacrificing the power to do other things that are very necessary for its own existence. It has ceased to live as an independent individual and has become a mere constituent part, an organ, of an individual of a higher order. Moreover, it sooner or later loses the power of reproducing itself by multiplication, becomes worn out and dies. So it is with the vast majority of all the cells of which the multicellular body is composed. They become worn out and die, and the body as a whole perishes, death being the inevitable price paid for progress. Certain cells in the body, however, escape the general débacle. These are the germ cells, and the reason for their exemption seems to lie in the fact that they never become highly specialised, never exhaust themselves by work, and never lose the power of multiplication. They survive and start the game afresh. They have been aptly compared to so many unicellular Protozoa enclosed within the multicellular body—in it but not of it—and, like the Protozoa, enjoying at least a potential immortality.

If we inquire how the multicellular condition arose from the unicellular in the course of evolution we find an answer in two directions. In the first place the existence of protozoon colonies—especially such forms as Volvox—shows us clearly the first step in the transition, and in the second place we see the actual process repeated with more or less accuracy in the development of all the higher animals from the unicellular egg. The division of the egg into embryonic cells or blastomeres in the process of segmentation is exactly comparable with the multiplication of an amoeba by simple fission. There is only one difference, and that is that the daughter

cells all remain together instead of separating. Somehow or other they have learnt the value of co-operation. At the close of segmentation, in a typical animal development such as that of a sea urchin, or even of so highly organised a form as Amphioxus, the embryonic cells arrange themselves in a form which exactly reproduces the arrangement seen in a colony of Volvox, giving rise to the blastula, a hollow spherical embryo with a wall composed of a single layer of cells.

It seems fairly certain, from such considerations, that the origin of all the higher animals is to be found in the habit, in which so many Protozoa indulge, of forming colonies, and the particular type of colony which has led to the best results appears to have been that adopted by Volvox and by the radiolarian Sphaerozoum. The branching type of colony, met with in the Vorticellidae and many other groups, appears to have led to no important advance in organisation, and we shall see presently that this holds true also in the case of higher divisions of the animal kingdom.

The mere habit of colony formation is not, however, sufficient to secure progress: there must also be differentiation and division of labour amongst the constituent cells, so that the entire organism may form a machine of greater efficiency in the struggle for existence. In this process the individual cells become mutually dependent upon one another—the whole colony undergoes what is termed integration, and comes to form a single individual of a higher order, an individual which cannot be separated into its constituent parts without perishing.

In such forms as Sphaerozoum, Volvox, and the blastula stage in the development of higher animals, the processes of differentiation, division of labour and integration have not gone very far, and such forms may still be regarded as mere colonies of single cells. In the main line of evolution of the animal kingdom the next step appears to have been the conversion of the hollow spherical colony of Protozoa into the coelenterate type, a process which is represented in every typical development by the conversion of the blastula into the gastrula.

If we accept the familiar principle of the recapitulation of ancestral history in individual development, we gain a very clear idea as to how the coelenterate type probably arose. The hollow sphere of one layer of cells became converted into a sac formed of two layers, with a mouth at one end leading into a primitive

digestive cavity. This process actually takes place in a variety of ways in the development of different animals at the present day, and we need not stop to inquire which of these ways represents most closely the course originally followed in ancestral history.

We have now arrived at a very definite type of multicellular structure—the gastrula of embryologists—with a well-marked differentiation of the constituent cells into two very distinct groups with widely different functions—an outer protective layer and an inner layer concerned in nutrition, known in embryonic forms as epiblast and hypoblast, in adults as ectoderm and endoderm respectively.

An organism possessing this type of structure has passed definitely beyond the stage of a mere colony of Protozoa, and constitutes what we may term an individual of the second order. The best and most familiar example of such an individual is the freshwater polype Hydra, which differs from an embryonic gastrula in little more than the budding out of tentacles around the mouth and a certain amount of histological differentiation amongst the constituent cells of both ectoderm and endoderm.

The organism has now gained a fresh starting-point for further evolution; there is a new unit of a higher order with which to build, and it is extremely interesting to see how the next really great advance begins, just as it did amongst the Protozoa, with colony formation.

Almost the only type of colony met with amongst the Coelenterata, however, is the branching type, but the mode of branching is extremely various. No great advance has been attained in this way, though some of the colonies produced are of much interest in discussing the problem of individuality. This is especially true of the Siphonophora, those freely floating colonies of Hydrozoa which form such an important constituent of the oceanic plankton. In many of these we find differentiation and division of labour amongst the constituent individuals carried to such a high degree, and accompanied by so complete an integration, that one is tempted to regard them as something more than mere colonies, for in such integrated colonies the constituent individuals tend to become converted into mere organs subserving the welfare of the whole and quite incapable of independent existence.

Take, for example, such a form as Nectalia or Physophora. Here we have a large number of individuals or zooids attached to a common stem. At the upper end a single modified individual forms a float. Along the length of the stalk two rows of differently modified individuals form swimming bells, which have concentrated their energies entirely upon the function of locomotion, and have completely lost the power of feeding themselves and of reproducing their kind. At the bottom of the stalk an expanded disc bears a number of other zooids. Some of these have mouths and stomachs, and fishing tentacles provided with thread cells, and their duty is to provide and digest food, not only for themselves but for the entire colony. Others, again, form protective shields or bracts, and yet others bear the germ cells upon which the organism depends for reproduction.

This is, clearly, a very highly organised type of colony. Whether, indeed, we should still call it a colony or regard it as an individual of the third order is a debatable question, and one which is of no vital importance, for we must remember that it is impossible to draw hard and fast lines across the path of evolution and say that all on one side of a given line is one thing and all on the other side something else.

At any rate, such colonies seem to have reached the limit of their progress, and have not afforded any fresh starting-point from which a new line of evolution has originated.

There are, however, certain other Hydrozoa which exhibit a type of colony formation that seems to foreshadow higher possibilities. I refer to the common jelly-fish known as Scyphomedusae. The hydroid phase of these organisms forms temporary colonies by a process totally different from branching. The entire hydroid divides transversely into a heap of little jelly-fish or ephyrae, resembling a pile of saucers. These remain together for a while and form a kind of colony known as a strobila, but presently they all separate and swim away.

Amongst the coelenterates this process of strobilation is never accompanied by any considerable differentiation and division of labour amongst the constituent individuals of the colony, and still less by integration, so that it leads to no higher type of organisation. When we come to the worms, however, which have undoubtedly arisen from coelenterate ancestors, we find in

many cases that the process of strobilation assumes much greater importance, and finally leads to a new type of structure characterised by what zoologists term metameric segmentation, or serial metamerism. The earthworm is, of course, a typical example of such a metamerically segmented animal, the body consisting of a number of distinct segments or metameres arranged in linear series one behind the other, and each one, to a certain extent, repeating the structure of all the others, each with its own division of the alimentary canal, its own division of the vascular system, its own division of the excretory system, its own division of the nervous system, and so on, but all united together in mutual dependence and incapable of separate existence.

Differentiation and integration have, indeed, gone so far in the case of the earthworm that we can no longer regard the animal as a mere strobila or linear colony. It is undoubtedly a single individual of the third order.

In some other groups of worms, however, the process of integration has hardly commenced, and the different segments sooner or later separate from one another as distinct individuals. We see a good example of this in the Planarian *Microstoma lineare*, where transverse division, frequently repeated, results in the formation of a strobila or chain of perfect individuals that only remain temporarily associated with one another. We see something of the same sort in the tape-worm, which consists of a chain of so-called proglottides attached to a head or scolex, and each containing, amongst other things, a complete set of reproductive organs.

Even in some of the highly organised chaetopod annelids, the group to which the earthworm belongs, we sometimes find new segments being added to the chain throughout life, by a kind of linear budding or transverse division, and in many cases groups of segments separate off from time to time as independent individuals.

The earthworm, however, has lost the power of reproducing independent individuals in this fashion. The process of integration has gone too far, for certain essential organs have become restricted to special segments and separation into constituent units is no longer possible.

The same phenomenon of metameric segmentation is exhibited throughout the whole of the great group Arthropoda, which

indeed are in all probability descended from annelid ancestor The common crayfish, for example, is made up of nineteen, or, according to some authorities, twenty segments, each having its own pair of limbs or appendages, all of which can be readily derived from one and the same common type of structure. In the arthropods, however, we find the process of integration carried much farther than it is in the annelids. Any ordinary insect, as you know, shows a well-marked differentiation into head, thorax and abdomen, each of which is composed of a number of segments which co-operate in the fulfilment of some common function, or rather of many common functions. There is not only differentiation and division of labour between individual segments, but the segments are grouped so as to perform their functions more advantageously.

It is precisely the same in the highest phylum of the animal kingdom, the Vertebrata. These are all metamerically segmented animals, derived in all probability from some metamerically segmented, worm-like ancestral form. The process of integration has gone so far, however, that but few indications are left, externally at any rate, of their origin ; though we see abundant traces of serial metamerism in their internal organisation, as for example in the segmented vertebral column and the segmentally arranged cranial and spinal nerves. In the early stages of development the metameric segmentation is much more obvious and cannot possibly be overlooked.

It may seem absurd enough to the layman to say that the human head is made up of at least twelve segments, each of which corresponds to a complete individual in some remote ancestral linear colony, but the statement is in all probability strictly true.

In the main line of evolution of the animal kingdom, then, we can recognise three very distinct grades or orders of individuality from the morphological point of view. First, the single cell, as in the Protozoa ; second, the simple multicellular type, as in the Coelenterata and the majority of the flatworms, and third, the metamerically segmented type, as in the annelid worms, the arthropods and the vertebrates ; and each succeeding higher grade has been derived from the one below it through the process of colony formation, followed by differentiation, division of labour and integration.

From this point of view it is clearly impossible to establish any definite criterion of individuality of general applicability, for it is impossible to say exactly when a colony ceases to be a colony and becomes an individual of a higher order. Our ideas of individuality change completely as we review the animal kingdom from the Protozoa upwards.

It might be supposed that some light would be thrown upon our problem by the study of the development of the individual from the egg, and this is certainly a very profitable line of inquiry. Can we say that we mean by an individual the whole undivided body into which the egg-cell develops? We certainly can in many cases, but there are many other cases in which we just as certainly cannot.

Let us return for a moment to the simple hydroid colony, as we see it, for example, in Obelia or Sertularia. Here the fertilised egg develops first into a single multicellular individual, but that individual does not stop developing when it has attained its full growth; it branches out and produces other individuals by a process of budding, and in the colony thus formed it is impossible to say where one individual ends and another begins, though it may be quite possible to tell how many individuals there are altogether by simply counting heads. It is not, as a rule, until many non-sexual individuals have been produced that some particular bud develops into a new sexual individual which once more produces eggs or sperm. Moreover, in this alternation of sexual and non-sexual generations the two generations generally differ widely from one another in structure, the sexual jelly-fish being strongly contrasted with the non-sexual hydroid polype.

A similar phenomenon of alternation or metagenesis occurs, of course, in many other animals and in all the higher plants, usually accompanied by great multiplication of the non-sexual generation by some process of budding. An ordinary tree is the non-sexual generation, and we can get as many individuals out of it as we like by taking buds or cuttings, though we are accustomed to look upon the whole tree as a single individual.

A difficulty of quite a different kind is presented by the lichens, which are well known to be composite organisms, made up of combined algal and fungal constituents, and by the myxomycetes, where the plasmodium is formed by the union of a number of separate amoebulae. Here we get a number of individuals,

originally quite separate, and even of different parentage, combining to form an individual of a higher order of quite a different nature from any produced by ordinary colony formation.

Such mixed individuals are rare in a state of nature, but various experiments show that they are quite easily produced artificially in certain cases. We can make mixed or composite individuals by the process of grafting both in plants and animals It is by no means difficult to graft together parts of two hydras. We can even join the hind part of one tadpole to the front part of another, and the product may develop into a complete frog, derived possibly from individuals of two distinct species.

Modern surgery has enabled us to perform marvellous grafting operations even upon the human subject. A few years ago an account was published of a girl whose knee-joint had been removed and replaced by that of another person, with perfect success. Theoretically, and apart from the difficulties of technique, there seems to be no limit to the possibilities of surgery in this direction. It would almost seem as if the whole organism were made up of a number of interchangeable standard parts, like a bicycle. Suppose it were possible to carry on the process until all the parts of the body had one by one been replaced by others, what would be the result from the point of view of individuality? Should we be able to say that the same individual still existed after all the operations had been carried through? It reminds us of the Irishman's knife, that at various times had had all the blades replaced and a new handle, but was still to him the same knife.

Other experiments have shown that it is possible to produce mixed individuals by joining together embryonic cells or blastomeres derived from different eggs. Garbowski in 1904 succeeded in uniting blastomeres derived from different embryos of a sea-urchin, either by hydraulic pressure or by squeezing them together by means of glass-headed pins. The fragments of the divided embryos were coloured intravitally with various stains that did not injure them, so that they could be readily distinguished from one another. Even when the blastomeres were taken from embryos in different stages of development, the composite embryos formed from their union developed into uniform pluteus larvae by means of various regulation processes.

An American biologist, H. V. Wilson, has shown that if a

hydroid colony, such as Eudendrium or Pennaria, be cut up into small pieces and then squeezed through fine silk gauze, it is reduced to a kind of cream or pulp in which the constituent cells are more or less completely separated from one another. If kept under suitable conditions, however, in pure sea-water, the separate cells join together again in irregular assemblages, to which Wilson has given the name "restitution masses," and such a restitution mass may behave like an embryo and develop into a new hydroid colony. The cells arrange themselves in the proper layers, ectoderm and endoderm; the ectoderm secretes a new horny perisarc, branches grow out, and finally new hydroid polyps are produced at the ends of the branches.

It is impossible in such a case to formulate any definite relations between the component individuals of the original colony and those of the new colony developed from the restitution mass. The whole thing was simply pulped, and the separated cells apparently reduced to an indifferent condition with powers of fresh association in new combinations, while many of the original cells seem to be used simply as food-material for the new colony.

This experiment is to some extent paralleled by what takes place normally in the development of the gemmules of the freshwater sponge. A number of wandering amoebocytes, charged with food-yolk, migrate to one spot in the parent sponge, and there become enclosed in the characteristic capsule secreted by surrounding cells. On germination the capsule is ruptured, and an amoeboid mass creeps out; the constituent cells behave like the blastomeres of an ordinary embryo, multiply rapidly and become differentiated into the various tissue cells, which arrange themselves in the manner characteristic of the adult.

Such phenomena certainly suggest the existence of some directive influence which enables the separate parts to co-operate in the formation of a whole individual, but what is the nature of this directive influence and where it is located are complete mysteries.

We have now inquired, so far as time permits, into the question whether or not it is possible from the morphological point of view to give any definition of individuality of general applicability. We have seen that in the course of evolution individuals of a lower order have given rise to individuals of a

higher order through the process of colony formation and integration, and that it is quite impossible to draw hard and fast lines between the successive terms of the series. We have seen also that even amongst highly organised plants and animals individuality does not depend upon the preservation of the same identical parts in the same association. Individuals may be subdivided and joined together in a variety of ways, and parts of different individuals may be interchanged without impairing their vitality. In short, we can by no means frame a general morphological definition of individuality.

Are we any better off when we ask what constitutes an individual from the physiological standpoint? A criterion of individuality is indeed often sought in the power to perform all the essential vital functions, or, in other words, to live a completely independent life. A unicellular organism does everything for itself. It feeds, respires, gets rid of its waste products and so forth, all in a very simple but at the same time efficient manner. A single cell of one of the higher plants or animals, on the other hand, though it may live independently for some time in a suitable medium, cannot do so indefinitely. It has sacrificed the power of doing everything for itself to the power of doing some one particular thing more efficiently, and depends for its continued existence upon the co-operation of innumerable other cells. Similarly, a single highly specialised individual of a siphonophoran colony, such as a swimming bell of Physophora, is quite incapable of independent existence; from the physiological point of view the colony as a whole constitutes the individual, though the morphologist has little difficulty in recognising the component members.

This leads us to the consideration of certain other cases of great interest. Many of the higher animals, though they do not form colonies in the morphological sense, have the habit of living together in social communities which we might regard as colonies of completely separated individuals. The honey bee is a familiar example. In a hive of bees we find individuals of three kinds, easily distinguishable from one another both by habits and by structural peculiarities. The queen is a perfect female, and is alone capable of laying eggs. The ordinary workers are imperfect females which have sacrificed the power of reproduction and concentrate their energies upon the collection

of food and other important services necessary for the welfare of the community as a whole. The drones are males; they do no ordinary work, their sole function being to fertilise the queen. None of these different kinds of individuals could live a really independent life; they are all mutually dependent upon one another. The morphologist, however, would not hesitate to regard them all as separate individuals, and I suppose the physiologist would probably agree with him. But, if we are to be strictly logical, from the physiological point of view the complete individual can be nothing less than the entire community. From this point of view, indeed, such communities might be looked upon as individuals of yet a fourth order, but in which, from the nature of the case, morphological integration is no longer possible. It is much the same with human societies, in which the component individuals become more and more dependent upon one another as civilisation progresses.

But, you may say, there can at least be no doubt about the individuality of my own self. I have my own personality, complete and indivisible. Here we approach the psychological aspect of our problem, into which I do not propose to enter. I have no doubt, however, that the psychologist would tell us that perhaps, after all, we may be mistaken in supposing that we can attain a sharply defined conception of individuality even in his province. Remarkable but, fortunately, abnormal cases are well known, in which two or more personalities alternate with one another in the life of what, from both the morphological and physiological points of view, we unhesitatingly call a single individual.

It appears, then, to be a hopeless task to seek for any biological criterion of individuality that can be applied to more than a very limited number of cases. We have constantly to modify our ideas on the subject as we pass from one group of organisms to another, and everything depends upon the point of view. It is certain, however, that, whatever else an individual may be, it is something which works as a whole for its own self-preservation and self-expression, and is more or less antagonistic towards other individuals with which it comes into relation in the struggle for existence.

Other facts that emerge quite clearly from our inquiry are that co-operation, differentiation, division of labour and

integration amongst individuals of successively higher orders constitute some of the most important factors by means of which organic evolution is carried on, and that at each successive stage of progressive integration a new individuality is acquired, the organism entering into possession of new attributes that are something very much more than the mere sum of the attributes possessed by its constituent units.

Individuality, though a very real phenomenon, is a very elusive one, and one which perhaps lies outside the legitimate domain of the biologist. We can do little more than collect the remarkable facts that confront us so frequently in the course of our investigations, and hand them over to the philosophers to deal with as best they can. How far the philosophers will agree that progressive evolution consists to a very large extent in the gradual merging of individualities of a lower order in others of a higher order I do not know, but to myself as a biologist this generalisation appears to hold a large measure of truth.

BRITISH HYDRACARINA: THE GENUS *LEBERTIA*.

By W. Williamson, F.R.S.E., and Charles D. Soar, F.L.S., F.R.M.S.

(*Read March 23rd*, 1915.)

Plates 33–34.

In his posthumous memoir published in 1879, under the title of "Description de quelques espèces nouvelles d'Hydrachnides du Lac Léman," * Lebert described a hydracarid which he considered to be new on account of the form of its genital area. He gave it the name of *Pachygaster tau-insignitus*, and he explained the specific name by referring to the resemblance which the light dorsal marking bore to the Greek letter *tau* (τ). As to why he selected *Pachygaster* as a generic name, he has left us in the dark. The selection, however, was not a happy one, as Meigen used it in 1803 (Diptera), Germar in 1817 (Coleoptera) and Gray in 1840 (Echinodermata).† In the year following the publication of Lebert's memoir, Neuman changed the generic name to *Lebertia*.‡ One can without difficulty comprehend how, from the lack of detail, several species were identified as *tau-insignitus*; and although some few species were described by Koenike and Piersig, it was not until after Sig Thor's exhaustive study of the genus that its comprehensive character was recognised. The result was, that although *tau-insignitus* had been naturally designated as type, the working out of the species which had been identified as *tau-insignitus* led to the creation of other species, so that, curiously enough, *tau-insignitus* was worked out of existence altogether. Sig Thor apparently recognised the illogical position which had arisen, for we find that later on he, in company with the late Prof. Forel, examined the locality at Morges where Lebert had obtained his specimens at a depth of 25 m. They were successful there in obtaining material which proved on examination to be quite distinct from anything previously described. As other representatives of the genus were not met with, one may conclude

* *Bull. Soc. Vaud.*, xvi. 327–377.

† *Nomen. Zool. Agassiz.*

‡ *Kgl. Sv. Vet. Akad. Handl.*, xvii. (3) 68.

with Thor that he and Lebert had obtained the same species in the restricted area. But in re-establishing the species, Sig Thor overlooked the fact that it had been previously designated as type, and consequently we find that the original genotype and the type of the sub-genus to which the genotype belongs are not the same species. Further we find that the sub-genus containing the genotype bears a different name from the genus, but one feels sure that the rules laid down for guidance in such cases by the International Zoological Congresses have been overlooked by the indefatigable Norwegian acarologist not by design, but purely by accident. To this we shall revert later.

A more troublesome matter, however, is the consideration of two of Koch's species as members of the genus *Lebertia*, viz. *Hygrobates iconicus* C. L. Koch, and *H. inaequalis* C. L. Koch, the former as a doubtful species, the latter as valid. These are represented in Koch's *Deutschlands Crustaceen, Myriapoden und Arachniden* in Heft 11–22/23 and Heft 11–20/21 respectively. As Koch's work is not to be found in many of our libraries, it will not be out of place to reproduce here Koch's descriptions of the above species; and as these can be taken as typical of the descriptions in Koch's great work, workers who have not hitherto had access to it will comprehend something of the difficulty attending the identification of many of Koch's species, difficulties which, moreover, are not rendered more easy of solution by his figures of species.

11. 22 foem., 23 mas.

Hygrobates iconicus.

H. subglobosus, flavus, nigro-pictus, pedibus ciliis nullis.

Gross, fast kreisrund, doch ein wenig länger als breit, gewölbt, glanzlos, zwei grosse Grübchen hinten an dem Mittelfleck, zwei auf dem Rücken des Hinterleibs, das Bruststück vorn in zwei Zähne verlängert. Die Taster mässig lang, ohne Auszeichnung. Die Beine dünn, die vordern kurz, kaum so lang als die Körperbreite, die hintern länger, alle kurzborstig, ohne Schwimmhaare.

Gelb, die Flecken braunschwarz oder schwarz: die Mittelfleck kurz, fast von der Gestalt eines Quadrats; die Seitenflecken bis zum Auge ziehend, breit, nicht lang. Die Rückenstreifen mit

dem Winkelflecken zusammenhängend, zusammen genommen zwei stark zackige Bänder vorstellend: der nach diesen Bändern seitwärts gezackte Gabelstreif heller gelb. Unten die Grundfarbe wie oben, die Zackenstreifen von oben durchscheinend, aber weiter von einander und in die Brust ziehend. Taster und Beine ocher gelblich, meistens etwas aufs erdgrüne ziehend.

Das Männchen ist kaum halb so gross als das Weibchen, meistens heller gefärbt, und der zackige Gabelstreif breiter, die Zackenstreifen aber schmäler.

Variirt ubrigens mannichfaltig, so dass Vorder- und Hinterleibsflecken zusammen fliessen, die ganze Rückenfläche schwarz färben und nur eine sehr schmale Spur des Gabelstreifs übrig lassen. Die Farbe der Beine verdunkelt sich bis zum schwärzlich grünen.

In dem Wiesengraben bei Zweibrücken im Monat Juli, nicht selten.

11. 20 mas., 21 foem.

Hygrobates inaequalis.

H. aurantiacus, furca angusta albida, maculis omnibus conjunctis, olivaceis, utrinque lobatis, pedibus breviusculis glaucis.

Kaum mittelgross, kurz eiförmig, der Rücken gewölbt, glänzend, mit sechs Grübchen, zwei beiderseits hinten am Mittelfleck, die zwei hintern davon von einander entfernter, die zwei des Hinterleibs auf der Mitte des Rückens einander mehr genähert; das Bruststück flach, stark vorstehend, beiderseits der Taster in eine scharfe Spitze verlängert. Die Taster ziemlich lang, dünn, die Beine aber stämmig, ziemlich lang, mit beweglichen büschelförmigen Schwimmhärchen an den vier Hinterbeinen.

Der Körper blass orangegelb, zuweilen auch ziemlich sattfarbig, Seiten- und Rückenflecken zusammengeflossen, olivengrün, mit hellern Punkten und Fleckchen, meistens aber zwei grosse seitwärts lappige Rückenfelder vorstellend; der Gabelstreif schmal, kurzarmig, mit zwei Eckchen auf dem Rücken; der Mittelfleck zuweilen aufs rosröthliche ziehend, entweder nur hinten durch eine feine Linie mit den Seitenflecken verbunden oder frei. Die Unterseite des Körpers gelblich, grün angelaufen, mit einem olivengrünen Schatten an den Hüften und einem Schattenstreif auf der Mitte. Bruststück, Taster und Beine bläulich grün.

Das Männchen ist nicht halb so gross als das Weibchen, hat mehr zusammengeflossene Rückenflecken und stets einen rostbraunen Mittelfleck des Vorderleibs; die Unterseite ist dunkler grün überlaufen und der durchscheinende Mittelfleck auf der Brust röthlich sichtbar. Bruststück, Taster und Beine sind heller und weniger stämmig. Am Hinterrande beiderseits ein Eindruck.

Variirt ins blassfarbige; bei sehr hellfarbigen Exemplaren fehlen die hintern Flecken und alsdann erscheint das hintere Drittel des Körpers durchsichtig weisslich.

Im Schwarzbach bei Zweibrücken in Rheinbayern sehr gemein.

It will be seen at once that Koch makes much of colour and of the shape of the colour patches, and as these, as Koch himself admits, are variable, dependence placed on them for identification is apt to lead to confusion. Nor do the scrappy structural details bring us any nearer a decision as to what precisely is intended. Some colour is lent to Sig Thor's contention that these are Lebertiad species in respect that *iconicus* is rough skinned (*glanzlos*), has no swimming hairs and has the epimera (Bruststück) produced into two sharp teeth, one on each side of the palpi. *Inaequalis* is smooth skinned, has swimming hairs and has the epimera as in *iconicus*. The first may belong to sub-genus *Lebertia* (= *Neolebertia* Sig Thor) or to *Pseudolebertia*. The second may be, as Thor has placed it, a *Pilolebertia* species. If we turn to Koch's figures, we observe that *iconicus* (fig. 23) alone represents the palpi with the long hairs so characteristic of the genus *Lebertia*, though not in any detail, merely indicating the existence of such. The ground is so uncertain that Thor admits with respect to *iconicus* that exact identification is out of the question and that the most that can be done is to record it as *Lebertia iconica* (C. L. Koch) sp. dub.

With regard to *inaequalis*, Thor admits the difficulty in deciding that figs. 20 and 21 represent the same species. If we consider what appears to represent the natural size of each, we are led rather to the view that instead of a male, fig. 20 represents a young nymph, which would probably account for the absence of swimming hairs on the second pair of legs. These are shown distinctly on the second pair of legs in fig. 21, though

the text only refers to swimming hairs on the two posterior pairs. Based on the capture of specimens of *Lebertia* at Zweibrücken (Koch's locality), which Thor believes to be identical with Koch's species, Thor has redescribed the species as *Lebertia inaequalis* (Koch, 1837) Sig Thor, 1900. This has been acknowledged as valid by Continental writers, for records have appeared since then from Switzerland, Italy and even from Turkestan.

As to the grouping of the component genera of the Hydracarina, various suggestions have been made. These have been discussed by Wolcott in his *Review of the Water Mites.** In his classification he groups *Nilotonia*, *Lebertia*, *Oxus*, *Frontipoda*, and *Gnaphiscus* as sub-family Lebertiinae. In Koenike's later classification † the sub-family Lebertiinae covers the last four of these genera, *Nilotonia* being transferred to another sub-family. Thor's *Prodromus*, ‡ published in 1900, included several other genera in addition to those noted by Koenike, and these Thor designated as Family Lebertiidae. The *Prodromus* does not discuss the matter, and owing to this want it does not appear to have obtained favour among acarologists. Probably Koenike's classification may be found to represent more closely than hitherto the natural grouping of the genera, but until we know more of the larval forms a definite expression of opinion must be postponed.

Sig Thor makes some interesting reflections on the phylogeny of *Lebertia*. In the absence of a sufficient knowledge of the larvae, he has had recourse to the nymphal forms in conjunction with the imagines for clues as to what course the line of descent might take. He conceives a hypothetical form *Urolebertia*, from which spring two other hypothetical forms, *Protoxus* and *Protolebertia*—the former leading up to *Gnaphiscus*, *Oxus* and *Frontipoda*, and the latter to the sub-genera of *Lebertia*. Of these, *Pseudolebertia*, *Hexalebertia* and *Mixolebertia* are the three branches which have a common hypothetical ancestor in *Protolebertia*. Descent is continued into *Pilolebertia* and *Lebertia* (= *Neolebertia*), the former appearing to have qualities which may be designated as of a dominant and the latter of a recessive type.

* *Trans. Amer. Micro. Soc.*, xxvi. 205.
† *Abh. Nat. ver. Bremen*, xx. 144.
‡ *Nyt. Mag. for Naturv.*, xxxviii. (3), 263–266.

Sig Thor's exhaustive study of *Lebertia* has shown that the genus can be resolved into two groups covering five sub-genera. In the first group the skin is dotted over with fine pores, and may be described as smooth, as it is without the papillae or ridges found in the second group. Swimming hairs are always present, though in rare cases these may be rudimentary. The spines on the extensor surface of the first segment of the fourth pair of legs also appear to lend themselves towards the discrimination of the groups, as the second group may have from five to ten, while the first group only has three or four, though *L. obscura* forms a slight exception, as it has five or six.

Two sub-genera, *Lebertia* (Sig Thor's *Neolebertia*) and *Pilolebertia*, belong to the first or smooth-skinned group, and these may be contrasted as follows:

In sub-genus LEBERTIA the body is rather elongate. The second pair of legs is without swimming hairs, while the third and fourth pairs have only isolated ones on the fourth and fifth segments. The number of these swimming hairs on each segment varies—may, indeed, even be wanting—but does not exceed four. It may be remarked here that in *L. subtilis* the swimming hairs appear to be entirely wanting. The third and fourth segments of the palpi are each fairly uniform throughout their length. The third segment has on its inner surface five long bristles; three of these are distal, the middle one being fairly close to that at the edge of the extensor surface. The fine pores on the flexor surface of the fifth segment are not very distinct, while the few small hairs on the extensor surface are entirely clustered at the distal end, one or two isolated ones being placed rather farther back. By Article 9 of the International Rules of Zoological Nomenclature (1905) *Neolebertia* is suppressed in favour of *Lebertia* as the name of the sub-genus.

In sub-genus PILOLEBERTIA the body varies from oval to nearly circular in outline. The second, third and fourth pairs of legs have numerous swimming hairs. Contrasted with sub-genus *Lebertia*, the third segment of the palpi is more like an inverted cone, while the fourth segment is rather curved. The inner surface of the third segment has also five bristles; three of these are distal, the middle one being distant from the edge of the extensor surface, not close to it as in *Lebertia*. The flexor surface of the fourth segment has two distinct pores well

separated, while all the small hairs on the extensor surface are distal.

In the second group the skin is either not dotted over with fine pores, or, where such are present, they are indistinctly seen ; but a more distinctive feature is the presence of papillae or of ridges varying in length. Species which are apparently smooth-skinned, but belong to this group, may be distinguished from the preceding group by the presence of *six* long bristles on the third segment of the palpi instead of five. As a rule, swimming hairs are either quite rudimentary or entirely wanting, but in some species, *e.g.* those with six bristles on the third segment of palpi, they are to be found.

Three sub-genera, *Mixolebertia*, *Pseudolebertia* and *Hexalebertia*, belong to this group.

In sub-genus MIXOLEBERTIA the skin may be papillose or finely granular, finely porose, rarely smooth. Swimming hairs are generally present. The inner surface of the third segment of the palpi possesses six long bristles, while as many as ten spines may be found on the extensor surface of the first segment of the fourth pair of legs.

PSEUDOLEBERTIA and HEXALEBERTIA have certain characters in common, in that they possess a skin which is apparently not porose, but is coarsely papillated or covered with ridges of varying length, and that they are devoid of swimming hairs; but otherwise they may be contrasted as follows :

In sub-genus PSEUDOLEBERTIA the third segment of the palpi has five long bristles, of which three are towards the distal extremity. One or two—more rarely three—of the fine hairs on the extensor surface of the fourth segment are more proximal than the others. The anal aperture is devoid of an outer chitinous ring.

In sub-genus HEXALEBERTIA the third segment of the palpi has six long bristles. The fine hairs on the extensor surface of the fourth segment are grouped about the distal extremity. The accessory claw and lamina at the distal end of the sixth segment of each leg are sometimes reduced in size. Anal aperture surrounded by a chitinous ring.

Fortunately material was available to enable Sig Thor to work out the nymphal characteristics of the sub-genera.

In sub-genus PILOLEBERTIA, the nymph has a very finely

ribbed skin dotted with fine pores. The epimeral area is relatively broad, with the provisional genital area lying well within the genital bay. The two long bristles on the extensor surface of the third segment of the palpi are distal, as well as the small hairs on the extensor surface of the fourth segment.

Sub-genus LEBERTIA also has a finely ribbed skin, dotted with fine pores, but the epimeral area is relatively narrower and longer, while the provisional genital area is set well back, sometimes quite outside of the genital bay. Of the two bristles on the extensor surface of the third segment of the palpi, one is about the middle of the segment and the other distal.

Sub-genus MIXOLEBERTIA has the skin strongly ridged and three bristles on the third segment of the palpi.

Sub-genus PSEUDOLEBERTIA has the skin ridged, but more sparingly than in the imago. The third segment of the palpi has only two long bristles.

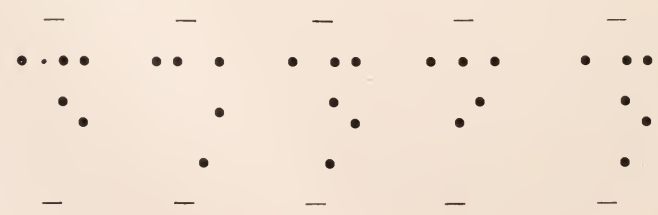
Sub-genus HEXALEBERTIA has the skin similar to *Pseudolebertia*, but the third segment of the palpi has three long bristles, one of these being much more proximal than the others.

Sig Thor has also proposed to establish the sub-genus DUROLEBERTIA to cover *L. solida*, but as that species appears to rest on material not too well preserved, the validity of *Durolebertia* must remain open until further material is available to prove its claims.

It may be here observed that American writers do not appear to favour subdivisions as outlined above.

As the long bristles on the third segment of the palpi are an important feature in the imago, the position of these on the type species of the sub-genera may be approximately represented as follows:

Lebertia.	*Pilolebertia.*	*Mixolebertia.*	*Pseudolebertia.*	*Hexalebertia.*
L. tau-insignita.	*L. insignis.*	*L. brevipora.*	*L. glabra.*	*L. stigmatifera.*



Between seventy and eighty species with varieties have been described. The species described here, in addition to the sub-generic types (excluding *brevipora*), are those found within the Britannic area.

In dealing with the appendages of the body, it is generally found convenient to designate the segments by number, the first being invariably that which is articulated to the body. No terminology has yet been agreed on, though Soar * and Koenike † have discussed the matter.

Lebertia tau-insignita (Lebert) Sig Thor.
(Sub-gen. *Lebertia*.)

1879. *Pachygaster tau-insignitus*, Lebert, *Bull. Soc. Vaud.*, xvi. 371.
1905. *Lebertia tau-insignita* (Lebert) Sig Thor, *Zool. Anz.*, xxix. 52–59, figs. 18–24.

This species, which has been redescribed by Thor, has, so far as known at present, a restricted range, being only recorded from the neighbourhood of Morges on the Lake of Geneva. It is the type species, and its inclusion here is therefore appropriate. Thor describes the body outline as resembling a long ellipse, whose length may vary from 0·90 mm. to 1·40 mm. The greatest breadth ranges from 0·80 mm. to 1·05 mm. The venter is weakly arched, the dorsum more strongly so. The anterior margin of the body between the antenniform bristles is rounded, or blunted. In this it differs from *L. fimbriata*, which Thor selected as type of the sub-genus to which both species belong, as well as with regard to the extent to which the anterior extremities of the second pair of epimera extend beyond the body margin; in the case of the present species they do not extend much. The skin is smooth and very finely porose. Sometimes, particularly in young specimens, the skin has an extremely fine striate appearance, due to the presence of very fine folds. These are in no way comparable to the coarse ridging of the skin such as may be observed in the sub-genus *Pseudolebertia*, but Thor's view is that they are provision for the increase in size of the body, since they become obliterated as growth proceeds. The colouring is unusual; it is almost entirely blackish, with a semi-transparent yellowish zone round the edge

* *Trans. Edin. Field Nat.*, v. 375.
† *Abh. Nat. ver. Bremen*, xx. 158.

of the body. On the dorsum is the yellow *tau*-shaped (τ) figure indicating the organ variously designated as the excretory organ and as the Malpighian vessel. The dark colour of the venter is relieved by white and yellow specks. The legs are transparent and tinged with green. Thor points out to what extent the colour of the body responds to various preservative solutions, and the necessity for caution in identification of preserved material in those cases where colour may be of some value in assisting identification. The palpi range from 0·40 mm. to 0·55 mm. in length, and are more slender than the first pair of legs. The second, third and fourth segments are covered with fine pores clustered together in groups, which are distributed fairly evenly over the segments. The bristles and hairs found distributed over the segments appear to be fairly constant in the sub-genus to which our species belongs. The first segment has only one slightly curved bristle at the distal extremity of the extensor surface. The second segment has three similar ones about the middle of the extensor surface, and at the distal extremity, but just towards the inner side, two long hairs about as long as the third segment. The long bristle at the distal end of the ventral or flexor surface is about as long as the segment itself, and is minutely pectinate. The third segment has five bristles, two about the middle, close to the extensor surface, and three extremely finely pectinate ones at the distal inner surface, one at the flexor edge and two at the extensor edge. The fourth segment has five fine hairs on its extensor surface, one in the posterior one-third, one about the middle, and the other three scattered about the distal extremity. The flexor surface has only one pore and rudimentary hair in its distal third. Concerning the function of the long flexor bristle of the second segment, Thor points out that when the palp is flexed, the bristle can enter the mouth and by a slight lateral movement can also enter the glandula globulosa. Thor's conjecture of the function may be expressed thus—the bristle enters the pore of the glandula globulosa, and by means of the pectination some of the secretion adheres to it. The secretion may then be conveyed to the claw of the mandible, and thus be used to paralyse the victim whose juices are to be extracted, or it may be conveyed by the bristle direct to the wound which the claw has made.

The epimera form a shield which may cover from one-half to two-thirds of the ventral surface, and in young specimens may even go as far as four-fifths, while in the case of gravid females the proportions may be entirely reversed. A change of colour also manifests itself, the prevailing tint being pale blue or violet. The inner sutures between the first and second pairs of epimera do not extend up as far as the exterior interval between the second and third pairs, and in this respect it is much shorter than Thor's type *fimbriata*. The inner end of the second pair is scarcely any broader than *fimbriata*. The lateral expansions of the third pair are large, while the inner ends of the fourth pair are somewhat, though not much, broader than the outer ends. The posterior edges of the epimera are not so thick as in some species. The length of the legs appears to be approximately, first pair, 0·80 mm.; second pair, 0·90 mm. to 1·10 mm.; third pair, 1·25 mm.; and fourth pair, 1·50 mm. to 1·60 mm. The various segments are comparatively long, markedly so in the three last segments of the two last pairs of legs, so that the considerable length of the legs is accounted for. The terminal segments are not so robust.

Thor has naturally compared the armature of the legs of this species with that of his type *fimbriata*, which he described in detail. Although they have much in common, certain differences, especially in the fourth pair of legs, are to be found. The outstanding features of *tau-insignita* are as follows: the fourth segment of the first and second pairs of legs has two or three fine long bristles on the extensor surface. The third pair of legs has three or four long pectinate bristles on the outer side of the third segment; the fourth segment has five bristles similar to those of the first and second pairs of legs, and is without swimming hairs. The fifth segment has three or four shorter bristles standing close together, and has two swimming hairs only. The greatest divergence is exhibited in the fourth pair of legs. The second segment has two or three short bristles distal on the extensor surface. The third segment has six pectinate spines ranged round the distal extremity. The fourth segment has six spines in a row on the flexor surface and one on the inner surface. All are rather flattened at the extremity. Six are pectinate, and swimming hairs are also wanting here. The fifth segment has six short pectinate spines almost in a row

on the flexor surface, and two swimming hairs only. The small spines of the sixth segment are generally six in number.

The genital area lies about one-fifth of its length out of the recess or bay formed by the inner ends of the epimera. The genital area is about 0·24 mm. in length, and at its broadest about 0·17 mm. The anterior and posterior sclerites for muscle attachment are not very robust. The valves are about 0·22 mm. in length, and have five pairs of coarse pores along their outer margins, and numerous hair pores along their inner edges. The hairs are long, reaching almost to the anus. The two anterior pairs of acetabula are very large, the posterior pair almost rectangular. The gland pores occupy the normal position. The anus lies about midway between the genital area and the posterior body margin. Sexual dimorphism appears to be limited, so far as external appearance is concerned, to the posterior region of the genital area being rather wider in the male than in the female, and to the hair pores along the edge of the genital valves being more numerous, viz. twenty-four to twenty-eight for the male, and twelve to twenty for the female.

Nymph.

Along with the imaginal forms, Thor obtained two nymphs, which bear so close a resemblance to the imago of this species, that he was constrained to accept them as nymphs of *tau-insignita*. The body in comparison is rather more extended, and is 0·68 mm. in length and 0·43 mm. in breadth. The skin is striate and minutely porose. The structure of the palpi is very much as in the imago, but the equipment of hairs is very much simpler. The hairs are confined to the extensor surface. The first segment is devoid of any hairs. The second has one small one midway, and two very long distal ones close together. The third segment has one long distal bristle and one a little way behind it. The fourth segment has two or three very fine hairs, of which one is well back, about or a little behind the middle. The flexor surface resembles that of the imago. The epimera differ from the adult form in that the fourth pair has the appearance of not being properly developed. The posterior angle has a little papilla-like projection. The legs are about 0·38 mm. long in the first pair to 0·75 mm. long in the fourth

pair, and have only from one-third to one-half the number of hairs and spines present in the adult. Only one or two swimming hairs are to be seen. The provisional genital area has no vulva, but two pairs of stipitate acetabula, surrounded by two semicircular chitinous structures, which almost meet together to form a circle.

Lebertia Soari Sig Thor.

1905. Sig Thor, *Zool. Anz.*, xxix. 55.

This species must be rejected, as it is founded on a diagrammatic representation of what was at the time considered to be the only species of the genus (vide *Science Gossip*, vi. 45, and relative figures).

Lebertia fimbriata Sig Thor.
(Sub-gen. *Lebertia.*)

1899. *Lebertia fimbriata* Sig Thor—*En ny hydrachnide-slegt og andre nye Arter—O. Norli, Kristiania*, p. 5. Pl. xviii. fig. 172-173.
1905. Sig Thor, *Zool. Anz.*, xxix. 41–52, figs. 5–17.

This hydracarid is of a dirty yellow colour, which is somewhat masked by the large brown patches and the broad pale-yellow strip on the back. It appears that the colour is apt to vary a little. The legs are more transparent and of a paler colour than the body. The epimera are about the same colour as the body, but more iridescent. The body is soft skinned, without any ridges or papillae, and has scattered over it many fine pores which are covered externally by a fine membrane. The gland pores, each accompanied by its fine guard hair, lie in four longitudinal rows and are conspicuous by reason of the strong ring which surrounds each of them. The length of the imago varies from abou 0·7 mm. to 0·9 mm., and if the anterior tips of the epimera are included may even reach 1 mm. Viewed dorso-ventrally the outline is a rather elongate ellipse, which is indented anteriorly between the antenniform bristles. The dorsal surface is arched very much more than the ventral. The tips of the first two pairs of epimera, each with a long, fine, weakly pectinate hair, are very noticeable beyond the anterior end of the body.

The capitulum is rather elliptical in shape. Only the anterior half is visible, the posterior half being concealed behind the epimera. The two anterior processes are long, tapering to a sharp point. *In situ* they are directed towards the posterior dorsal surface, but have very little tendency to spread apart laterally. The posterior processes are very much shorter, but similar in shape. Their direction, however, is straight into the body, so that they partially enclose the pharynx. The pharynx itself is fairly wide and thick and increases in size gradually towards the posterior extremity. The mandibles are long and slender, extending well beyond the posterior end of the pharynx, and work in a furrow formed in the hinder wall of the capitulum. The claws are very nearly straight and are weakly serrate. Opposed to the claw is a laminar process which is nearly as long as the claw.

The palpi vary in length from 0·35 mm. to 0·40 mm. The third segment is shorter than the second, and the second shorter than the fourth. They are thinner than the first pair of legs and are laterally compressed. The second segment has a long finely pectinate bristle on its flexor surface, slightly back from the distal end. On the inner side of the segment almost distal and close up to the extensor surface there are, close together, two bristles which very nearly attain the length of the third segment. The third segment has five weakly pectinate bristles on its inner surface. Of these, three very long ones are at the distal extremity, the fourth is short and situated close to the extensor surface and slightly behind the middle, the fifth is longer than the fourth and a little in advance of it and rather more to the inside. The three distal ones are generally about the length of the fourth segment; one of these is close to the flexor surface and two close to the extensor surface, one being slightly in advance of the other.

The fourth segment has only one small pore and rudimentary hair in the distal third of the flexor surface. The extensor surface has five or six fine short hairs of which three are distal, one about midway and the others between.

The posterior end of the first pair of epimera lies about midway between the capitulum and the genital area. The posterior end of the second pair is fairly broad. The suture between the second and third pairs extends up about half-way to the gland

plate on the outer border and then continues as a filiform extension coming well up towards the first pair. The third pair is triangular with its suture extending inwards for about three-fourths of the distance to the genital area. The fourth pair is also three-sided, the outer side being not straight, but curving well round to the inner posterior corner. The epimera are perforated by numerous pores which are visible externally as groups of fine pores.

The legs all have the first three segments short and the last three long, and in addition it will be noted that the terminal segments are rather thicker towards the distal extremity. The first segment of all pairs of legs has three or four short spines on the extensor surface; in the case of the second and third pairs of legs, one of these is longer, flattened and bipectinate; in the fourth pair of legs the segment is much larger than in the others. The second and third segments apparently have some latitude in their equipment of spines, but the distal ends have one or two of these flattened bipectinate spines. The fourth segment of the third pair of legs has one swimming hair, and the fifth segment has three. The fourth segment of the fourth pair of legs resembles that of the third pair, while the fifth segment has two or three swimming hairs. The claws have a short thin lamina.

The genital organ is pyriform in outline, the narrowed anterior end being united to the epimera by a subcutaneous chitinous strip. Posteriorly, the genital area extends for about one-third of its length beyond the epimera and is bounded by an arc-shaped chitinous ridge. The anterior sclerite is short and thick. The two anterior pairs of acetabula are roughly rectangular, with rounded corners, and are about twice as long as broad. The posterior pair are more nearly round. The porose covering valves have four or five large hair pores along their outer edge, and along the inner edge there is a larger number of fine pores, which varies with the sex, numbering in the female about twelve pairs and in the male about twenty. The anal orifice lies about midway between the genital area and posterior body margin.

L. fimbriata has been taken in Surrey and Suffolk. Halbert's *fimbriata* of the Clare Island Survey has been redescribed as *L. celtica* Sig Thor.

Lebertia celtica Sig Thor.
(Sub-gen. *Lebertia.*)

1911. *Lebertia fimbriata* Halbert, *Proc. Irish Ac.*, xxxi. (39i) 22, plate iii. fig. 31.
1911. *L. celtica* Sig Thor, *Zool. Anz.*, xxxviii. 330.

Two specimens were taken at Clare Island and recorded as *fimbriata.* From the short note and figure accompanying the record Sig Thor came to the conclusion that these were sufficiently distinctive in character to warrant a new species, *L. celtica.* At first, Thor's new species did not seem to be well grounded, and *fimbriata* var. *celtica* appeared to be better able to meet requirements. Careful examination of the types, however, leads to the rejection of a mere variety in favour of *celtica* n.sp. In support of this may be cited the elongate body form and relatively contracted epimera, and the skin externally smooth but with traces of ridges, either suppressed or of a rudimentary type.

The body is about 0·9 mm. long and 0·6 mm. broad. The noticeable feature is the evenness of the sides, so that the body is of about the same width throughout. The posterior end is rounded, while the anterior end has a triple indentation, viz. one at each of the corners and one between the antenniform bristles. The colour is a golden brown, with dark patches on the dorsum. Legs and palpi are greyish. Gland pores are arranged in four rows on the dorsum; each pore has a diminutive guard hair, and is protected by a strong ring. The capitulum measures about 0·22 mm. in length, and the mandibles about 0·25 mm.

At present details as to the capitulum are not available, but these will no doubt become so after further dissections of the type have been made. The palpi are thinner than the first pair of legs, and measure about 0·27 mm. in length. The armature of bristles is as follows: on the extensor surface of the first segment one bristle, and on that of the second segment three short and two long ones at the distal end. The usual long bristle is to be found on the flexor surface. The third segment has the distal extremity rather stouter than is to be found in *fimbriata.* The five bristles on the inner side occupy practically typical positions, but the posterior one of the five appears to be much longer than the corresponding one of *fimbriata.* The flexor surface of the fourth segment is almost straight, and has only

one pore in the distal third accompanied by a diminutive hair. The extensor surface bulges out somewhat, and gives the impression of a flattened arch. It has only one short hair midway and two similar distal ones, one on each side. The fifth segment, which is conical, ends in three claws, of which the back one is smaller than the other two. The pores on the segments are not large, but they are fairly evenly distributed right up to the distal end of the fourth segment.

The epimera are rather long in comparison to the breadth, but this may be due to the fact that the sides are rather drawn in towards the body, so that the whole epimeral area has a slightly arched appearance. Anteriorly the epimera extend well beyond the body margin. The first pair of epimera extends posteriorly to half-way between the capitulum and the genital area. The posterior ends of the second pair are broadened out, and the suture which separates them from the other pairs extends well up and tends to draw in towards the first pair. The suture between the third and fourth pairs goes well on towards that of the second pair, so that the third has an almost triangular appearance. The fourth pair also may be described as three-sided, as the outer side sweeps round from the third pair to the genital area. The posterior corner in one of the specimens is rounded, in the other it is truncated.

The first pair of legs measures 0·60 mm., the second pair 0·67 mm., the third pair 0·74 mm., and the fourth pair 0·87 mm. At the base of each of the well-developed claws of the first two pairs of legs there is a small claw-like process. The sixth segment of the first pair of legs increases in thickness towards the distal end, and is coarsely porose. The inner surface is without hairs or spines. The fifth segment is similar in size and shape to the foregoing, and has only one flattened spine and two or three short hairs at the distal end. The fourth segment, though somewhat similar, is rather stouter. The third segment is shorter and stouter, with one flattened weakly pectinate spine and three or four short ones distal. The sixth segment of the second pair of legs is similar to that of the first pair—it is, however, a little longer and more slender. The fifth segment is a little longer than the sixth, and has three or four short spines and one or two short fine hairs at the distal end. The fourth is proportionately longer and stronger

than the foregoing, and has six or seven strong spines round the distal end and three or four round the middle. The third segment is shorter and stouter, and has five or six spines round the distal end and three or four round the middle. One of the distal spines is more like a bristle.

The third pair of legs has one short fine hair on the distal half of extensor surface of sixth segment. The fifth segment has *one* moderately long fine distal hair and one or two short spines about midway. The fourth segment has six or seven spines of varying length round the distal end and four or five round the middle. The third segment has four or five spines of varying length and stoutness round the distal extremity, and a similar number of shorter ones round the middle.

The sixth segment of the fourth pair of legs has two short spines on the distal half. The fifth segment has *two* moderately long fine swimming hairs and five or six short thin spines at the distal end. There are six or seven short thin ones on the inner edge and two short ones on the outer edge. The fourth segment has five or six short spines along the inner edge and four on the outer side.

The valves of the genital area lie close up to the posterior ends of the second pair of epimera and extend posteriorly beyond the epimera for about one-fourth of their length. Along the inner edge of the valves there are about seven pairs of hair pores. The two anterior pairs of acetabula are long and narrow. The posterior pair are shorter and broader.

Lebertia insignis Neuman.

(Sub-gen. *Pilolebertia.*)

1880. *Lebertia insignis* Neuman. *Kgl. Sv. Vet. Akad. Handl.*, xvii. (3), 68–70, pl. viii. fig. 4.
1906. Sig Thor, *Zool. Anz.*, xxix. 784–790, figs. 50–53.

Viewed from the critical standpoint from which the genus is now considered, it is not to be wondered that Neuman's description, written about thirty-five years ago, should treat rather differently some details which recent writers have considered of some moment. Any doubts, however, which might have arisen as to Neuman's species can now have little force, as Sig Thor has

examined Neuman's type specimen and supplied what was deficient in the original description.

The species is distinguishable first of all by its small size, which is variable and may range from about 0·8 mm. in length to slightly over twice that size. The greatest breadth is a little under that figure. As a rule the body is somewhat dorso-ventrally compressed and varies from a broad oval to nearly round. The anterior is without any weak marginal indent—rather bluntly rounded. The apical extremities of the first and second pair of epimera extend only slightly beyond the body margin.

The colour may be a reddish brown or a yellowish red with large brown spots, with the excretory organ showing through as a broad T- or Y-shaped strip on the dorsum. The epimera have a tinge of blue or green. The palpi and legs may also have these colours or even a bright red, but in these appendages the colours are fairly transparent.

Beyond being thinner, the skin is similar to that of *porosa*. The capitulum also resembles that of *porosa*, but it is decidedly smaller. The tapered anterior processes are of moderate length and do not spread out very much laterally. While the mandible closely resembles that of the allied species, it is also more symmetrical in its build. The posterior portion is weakly sinuate with the extremity sharply turned up. The pharynx, like the mandible, is also more symmetrical.

The palpi appear to have some latitude in regard to their length, as the extremes of 0·30 mm. and 0·48 mm. have been recorded. The Irish specimens are even larger, viz. 0·52 mm. The second segment has five or six bristles on the extensor surface, while the characteristic bristle on the flexor surface is short, and though it is distinctly back from the distal extremity of the segment, it is not so much as is to be noted in, say *porosa* or *obscura*. The third segment has five long finely pectinate bristles on the inner side. Three of these are close to the extensor edge. The proximal and distal ones each stand slightly back from their respective ends of the segment, while the middle one is more on the edge than the other two. The remaining two stand close together distally almost at the flexor edge. This feature rather marks out *insignis* from other species of the sub-genus. While the middle one of the three distal bristles is typically towards the

flexor surface, this appears to be more decidedly shown in *insignis* (Thor's two figures do not agree as to this. Cf. *Zool. Anz.*, xxviii. 821, fig. 1, and xxix. 788, fig. 53). All the short fine hairs on the fourth segment are distal.

The epimera are relatively larger than in sub-genus *Lebertia*. As a rule the breadth is greater than the length. The lateral extensions of the epimera embrace that portion of the sides abutting on the epimera. It must be remarked here, however, that these extensions can only be observed in certain positions if the creature is not dissected. In preparations where the epimera are removed, or the body is flattened out, the extensions can be readily seen. The first pair of epimera is of normal form. The second pair is narrow and of almost uniform width throughout. If the suture between the third and fourth pairs were continued for the full length, it would just about meet the inner end of the suture between the second and third pairs, showing the third pair to be almost triangular in form. The fourth pair is broader at the inner end than at the outer. The outer edge is lightly rounded.

The legs measure up to 1·00 mm. in the first pair, 1·25 in the second pair, 1·70 mm. in the third pair and 2·05 mm. in the fourth pair. The fourth, fifth and sixth segments of each pair of legs are much longer than the other segments. The sixth segment of the second, third and fourth pair of legs is more or less thicker at the distal extremity than at the proximal. The first segment of the fourth pair of legs, which is much larger than the corresponding segment of the other pairs, has on its extensor surface one or two small proximal bristles and distally two much longer ones. The flexor surface has one distal bristle with two accompanying hairs. The flexor surface of the sixth segment has generally only three spines. The swimming hairs are short, relatively few and variable in number. The fifth segment of the second pair of legs may have from five to seven. With respect to the third and fourth pairs of legs, the fourth segment may have up to eight, and the fifth segment up to twelve.

The genital area extends a little beyond the epimera. Posteriorly it is bounded by a thick chitinous curving ridge and anteriorly by a stellate sclerite which forms a bridge between it and the epimera. The valves and acetabula are of normal form. Along the inner edges of the valves there are a number of hair

pores, ranging in the female up to sixteen, and in the male up to twenty-five.

Nymph.

The nymphs are about 0·60 mm. in length and 0·50 mm. in breadth. The fifth segment of the second pair of legs has two swimming hairs. The fourth segment of the third and fourth pair of legs has only two swimming hairs, and the fifth segment only four swimming hairs. The flexor surface of the sixth segment of the fourth pair of legs has only one small spine.

This species has been found in Great Britain and Ireland, as well as Norway, Sweden, Finland, Germany, Switzerland and Italy.

Lebertia vigintimaculata Sig Thor is now considered by its author to be merely a variety of the above and other species (vide. *Zool. Anz.*, xxix. 786).

Lebertia porosa Sig Thor.

(Sub-gen. *Pilolebertia.*)

1897. *L. tau-insignita et insignis* Thor. *Ark. Math. Naturv.*, xix. (6) 31 ; xx. (3) 18.
1900. *L. porosa* Thor. *Nyt. Mag. Naturv.*, xxxviii. 273.
1905. Sig Thor, *Zool. Anz.*, xxix. 761.

Lebertia porosa is one of the species attaining a large size. Considerable variation appears to exist with regard to length, as specimens have been recorded from 0·9 mm. up to 2·1 mm., with a corresponding breadth varying from 0·85 mm. to 1·9 mm. The most common length appears to be about 1 mm. or a little over, and the breadth about 0·1 mm. less than the length. The body is oval to almost round, frequently slightly dorso-ventrally compressed. The anterior end is rounded, with the apices of the first and second pairs of epimera extending a little beyond it. The colour is a dark reddish brown or a yellowish red with brown spots, with the excretory organ showing through as a bright-yellow T-shaped dorsal figure. The epimera may show a faint bluish or greenish tinge, while the palpi and legs are more transparent, and evidently more variable as to colour, as red, green, blue, or bluish green are found. Thor has pointed out that the action of preservative solutions on the

colours is erratic. Thus, for example, of two specimens subjected to identical treatment, one may bleach out, while the other retains its colours, or all or part of the dark spots may remain while the rest of the colour may fade. Thor conjectures that the condition of the dermal glands may have some bearing on this question. The skin is rather thick, smooth and strewn over with fine pores.

The anterior maxillary processes are long and broad, tapering to a point, and extend in an upward, lateral direction towards the posterior, but not so far as to meet the pharynx or the posterior processes. The latter have their extremities curved upwards so as, in a manner, to enclose the pharynx.

The palpi are laterally compressed, and are thinner than the first pair of legs. The length varies from 0·4 mm. to 0·6 mm. The third segment is always shorter than the second and fourth segments. It should be noted that compared with the second and third segments, the pores of the fourth segment are much finer. These gradually disappear towards the distal extremity, so that that region has a very much smoother appearance. The first segment has only one short slightly curved bristle on its extensor surface, where the second segment has six or seven. Of these the two distal ones are long and thin, and stand back from the distal extremity of the segment. The characteristic fine pectinate bristle on the flexor surface is weak and not particularly long, being generally about half the length of the segment or a little over that. The third segment has five finely pectinate bristles; one of these is proximal and close to the second segment, while another is about the middle, rather more on the extensor surface than on the inner. These two are generally shorter than the other three, which are distal, and about the length of the fourth segment. The middle one of that three is about equidistant from the one on each side as in *obscura*. The fourth segment has two distinct pores on its flexor surface, each with a rather rudimentary hair. One of these pores is in the proximal third, the other may be so far forward as to be in the distal third. The five fine hairs on the extensor surface are all distal. The fifth segment is small, almost conical, ending in two small claws lying close together, with a small one behind them.

The epimera agree very closely with those of *insignis*, with the exception that the inner ends of the second pair are much

broader in *porosa* than in *insignis*. The inner corners of the third and fourth pairs of epimera are more rounded, not so acute as in *insignis*. All the sutures and margins are thick, the inner ones particularly so.

Some variation appears to manifest itself with regard to the length of the legs, but in general it may be said that the two anterior pairs of legs are short, and that the two posterior pairs attain something like the length of the body or a little over. The sixth segments are either weakly thickened or not at all. The sixth segment of the first pair of legs is not thickened, but reduced in length. The thickening of the corresponding segment of the second pair of legs is scarcely appreciable, more so, however, in that of the third and fourth pairs of legs. The first three segments of each pair of legs are the shortest, the other three the longest. In comparing the first segment of each pair of legs, it will be noticed that that of the fourth pair of legs is by far the longest. Swimming hairs are entirely wanting in the first pair of legs. The second pair has a small group clustered at the distal end of the fifth segment; these are not so long as the succeeding segment. The third pair has five to ten long swimming hairs at the distal end of the fourth segment, and eight to fifteen at the end of the fifth segment. The fourth pair of legs has five to nine long hairs at the distal end of the fourth segment, and anything from eight to seventeen at the end of the fifth segment. The claws appear to be of normal form, a large thin claw with a thin broad laminate base, and in the narrow interval between a small accessory claw.

The genital area is fairly typical in form, and extends but little beyond the epimera. The male is distinguishable from the female by the greater breadth posteriorly in the valves and by the number of gland hairs along the inner margins, viz. twenty to thirty-three where the female has only from fourteen to twenty. The large pores along the outer margin are few in number, not more than five pairs at the most. Of the sclerites which serve for muscle attachment, the anterior one is triangular in shape, with its apex continued into a narrow bridge to bind it to the epimera. The posterior one is broad and porose, and is more like a semicircle in outline. The two anterior pairs of acetabula are long and narrow, rather rectangular, with rounded corners. The posterior pair is much shorter and broader.

Nymph.

The nymph is about 0·70 mm. in length and about 0·65 mm. in breadth. The palpi are pretty much like those of the imago so far as the structure is concerned, but in respect to the number and arrangement of the bristles there is a marked difference. The first segment has none at all; the second has two on the extensor surface and one distal. The third segment has only two long bristles, both distal, one on the extensor surface and one midway on the inner surface. The distal extensor surface of the fourth segment has only three short ones, in other respects it resembles the imago. The provisional genital area does not extend beyond the epimera. The surrounding ring, which is in communication with the epimera anteriorly by a small sclerite, has about six fine pores. The four acetabula are stipitate.

Var. *britannica* Sig Thor covers some British specimens which have the posterior pair of acetabula about the length of the second pair instead of much shorter as is usually the case (*Zool. Anz.*, xxix. 776).

Var. *vigintimaculata* Sig Thor has presumably the same characteristics as the variety of the same name under *L. insignis* (*ib.* 786).

Var. *dorsalis* Sig Thor has the middle distal bristle of the inner surface of third segment placed more towards the extensor surface (*ib.* 779).

Var. *italica* Sig Thor. Specimens from Lake Maggiore have the legs, epimera and palpi of a decided greenish-blue colour (*ib.* 779).

These latter forms are evidently local, but it is open to question whether they have sufficient claim to be ranked as varieties.

Lebertia porosa has been recorded for Britain and appears to have a fairly wide distribution, as even Siberia has added its quota to the recorded distribution.

Larva.

The outline is approximately oval, and measures about 0·3 mm. in length and 0·2 mm. in breadth. The body is dorso-ventrally compressed, and this applies particularly to the posterior region. The dorsum and venter are both protected, the former by a chitinous plate, which extends nearly to the edge of the

body, and the latter by the epimeral plate, which is similar in size to the dorsal plate. The skin of the lateral surface between the edges of the plates is soft and marked by fine lines running the length of the body. Along this area dorsally there are nine pairs of long stiff bristles in two rows, an inner of four pairs and an outer or more lateral one of five pairs. The dorsal plate has three pairs—two pairs lying close in front of the eyes and a small pair representing the antenniform bristles. The ventral surface also has a few hairs—two pairs on or near the edge of the epimeral plate posteriorly being pectinate. Quite a number of these hairs may extend beyond the margin of the body.

The capitulum is about 0·08 mm. long. It extends well beyond the bay formed by the first pair of epimera, and curves well towards the ventral surface. About midway up each side the palpi are articulated. The third and fourth segments are prominent by reason of their stoutness. The third segment has one strong bristle on its outer side, while the fourth has a moderately long curved claw. The fifth segment is of a rudimentary type: it lies somewhat recessed into the fourth segment, and has two long and three short hairs springing from it.

The larva possesses only three pairs of legs, which are grouped well towards the anterior end of the body. The first pair may measure up to 0·20 mm., the second pair 0·27 mm., and the third pair 0·30 mm. Swimming hairs are entirely wanting, but locomotion is aided by a varying number of moderately long, simple or weakly pectinate straight bristles, which are to be found in greatest abundance on the third pair of legs. Each leg ends in three fine, long, curving claws, of which the middle one is the smallest.

Corresponding to the number of pairs of legs, there are only three pairs of epimera. The suture dividing those of one side from the other is well marked, as well as that dividing the first pair from the second. Only a very short rudimentary lateral suture separates the second pair of epimera from the third. The posterior portion of the third pair is cut away obliquely on the median line; within this recess there is a small weakly chitinised post-epimeral plate, which Piersig called the anal plate, but which Thor prefers to consider as the rudiment of the provisional genital area found in the nymph.

Lebertia obscura Sig Thor.
(Sub-gen. *Pilolebertia*.)

1900. *Lebertia porosa* var. *obscura* Sig Thor. *Nyt. Mag. Naturv.*, xxxviii. 273, pl. x. figs. 3 and 4.
1902. *L. obscura* Sig. Thor in *Arb. Inst. Wien,* xiv. (2) 11, pl. i. fig. 9.
1906. Sig Thor, *Zool. Anz.*, xxix. 780, figs. 47–48–54.

Lebertia obscura was, by reason of its closeness to *L. porosa*, first considered by Thor to be only a variety of that species, but his exhaustive investigations on the genus led him to elevate *obscura* to the rank of a distinct species. When *obscura* and *porosa* are contrasted, it will be noted that the former is somewhat the larger of the two, ranging from 1·5 mm. to 2·5 mm. in length, and in general it appears to be of a more robust build and somewhat darker colour.

The palpi measure up to about 0·65 mm. in length, and viewed ventrally are scarcely so stout as the first pair of legs. Compared with *porosa* the long bristle on the flexor surface of the second segment is relatively shorter and situated rather more distally, the third segment is shorter in proportion, while the fourth is broader and straighter, with the two pores on the flexor surface frequently situated close together. As a general rule the fifth segment is shorter and more blunted.

The legs are thick and strong. The first pair measures about 0·96 mm., the second pair about 1·36 mm., the third pair about 1·70 mm., and the fourth pair about 1·92 mm. in length. The fourth pair is to be noted as possessing in the fifth and sixth segments a larger number of spines and swimming hairs than in the closely allied species, and also what Thor deems a characteristic, the possession of 5 or 6 spines, 3 or 4 of these being distal, on the extensor surface of the first segment, instead of the 3 (more rarely 4), 2 of them being distal, generally associated with other *Pilolebertia* species.

L. obscura does not appear to be a widely distributed species, as so far it has only been reported from Norway, Scotland and England.

Lebertia Halberti Koen.
(Sub-gen. *Mixolebertia*.)

1902. *Lebertia Halberti* Koenike, *Zool. Anz.*, xxv. 610.

This species was taken by Halbert at Dartrey in Ireland in 1899, and so far only the male appears to be known. In outline the body is oval, being about 1·36 mm. in length and about 1·20 mm. at its broadest part. The colour of the body is a dark green—described by Koenike as a greenish grey—the dorsal surface being adorned on each side of the median line by a row of roundish dark spots. As is not uncommon, the colour of the limbs and palpi is much weaker than that of the body. The skin is without the strong ridges noticeable in other species, but, notwithstanding, it is adorned by fine lines crossing one another as to form an elongated meshwork.

The palpi are 0·43 mm. in length, the segments being respectively 0·04, 0·10, 0·10, 0·16 and 0·03 mm. in length, and in their bristle armature they closely follow the type. The first segment has one short distal, slightly curved spine on the extensor surface. The second segment has two similar but rather larger spines on the middle of the extensor surface, and on the distal inner surface adjacent to the extensor surface two moderately long bristles. The distal flexor surface is armed with the usual long bristle. A noticeable feature is the presence of six bristles, extending nearly to the distal end of the fourth segment, on the inner surface of the third segment. Three of these are distal, one being adjacent to the flexor surface and the other two close up to the extensor surface, one being practically on the extensor surface. Of the other three, one is proximal, while the remaining pair is situated about midway and occupies about the same position as the pair anterior to it, if anything rather more towards the extensor surface. The fourth segment has four fine hairs grouped at the distal extensor extremity. The posterior of the two pores on the flexor surface is accompanied by the typical moderately long hair.

The lateral processes at the anterior end of the capitulum have very little tendency to spread out laterally—they extend inwards until their extremities are about in line with the base of the posterior pair. The claws of the mandibles have a row of fine teeth on their concave side.

The legs are rather more slender than in *L. insignis*, and this may be attributed to the fact that the fourth, fifth and sixth segments of the second, third and fourth pairs of legs are decidedly longer. The fifth segment of the second pair of legs has swimming hairs, the length of which about equals that of the segment itself.

The inner posterior ends of the second pair of epimera just in front of the genital valves are decidedly thickened, and are about twice as broad as in *L. insignis*. The fourth pair of epimera is nearly of equal width throughout, any tendency to increase manifesting itself towards the inner end, where the posterior corner is broadly rounded off.

The genital area extends for about one-third of its length outside the bay formed by the fourth pair of epimera. The thick chitinous ridge which forms the posterior boundary of the area lies close in and extends a little way up the sides. The third pair of acetabula is very little shorter than the other two pairs. A few hairs may be noted along the posterior margins of the valves.

Lebertia glabra Sig Thor.
(Sub-gen. *Pseudolebertia*.)

1897. *Lebertia glabra* Sig Thor, *Arch. Math. Naturvid.*, xx. (3), 19, pl. iii. fig. 23.
1907. Sig Thor, *Zool. Anz.*, xxxi. 105–115, figs. 73–81.

Lebertia glabra appears at present to be limited to Norway and Scotland. It belongs to the smaller species, and appears to vary from about 0·6 mm. to 1·1 mm. in length, and about 0·5 mm. to 1·0 mm. in breadth. In outline, the body presents a somewhat rounded appearance, and, viewed from the side, the venter is seen to be much less arched than the dorsum. The dorsal surface is of a brownish-yellow colour with dark-brown patches, and is rendered conspicuous by the pale-yellow T-shaped figure of the excretory organ showing through. The ventral surface and the legs have a tinge of green in their colouring. The skin is covered with short chitinous ridges, some of which may even be forked. On the dorsal surface these are quite short and lie more or less parallel to the long axis of the body. On the ventral surface they are longer and run transversely. In

proximity to the epimera, genital and anal areas the ridges to some extent follow the outline of these more highly chitinised structures. The skin would appear to be thin, as Thor has been unable, except in isolated cases, to detect the groups of fine pores which are prominent in other species, though the epimera, genital valves, legs and palpi exhibit the coarsely porose appearance to be found throughout the genus.

The capitulum is of the form normal to the genus, and is about 0·22 mm. in length, with a breadth of nearly 0·12 mm. It does not fully take up the area bounded by the inner margins of the first pair of epimera. While the anterior processes of other species have an upward and outward tendency, *i.e.* towards the interior of the body, in this species they are more slender and come closer in to the capitulum, lying more in a horizontal direction and less towards the interior of the body. The posterior processes are fairly slender. The mandibles, like the anterior processes, are more drawn in towards the capitulum than is usually the case. They are fairly long, and extend beyond the pharynx and the extremities of the anterior processes. An average length for the palpi would appear to be slightly over one-third of a millimetre. The fourth segment is longer and thinner than the two preceding ones, while the fifth is relatively long and thin and tapered. The extensor surface of the first segment has one long fine bristle. The corresponding region of the second segment has four bristles, of which the two longest are almost distal, while on the flexor surface, set well back from the distal extremity, there is a strong, curving bristle, which is moderately long and finely pectinate. The inner surface of the third segment has five bristles; three of these are distal, finely pectinate, and about as long as the fourth segment. The middle one of the three lies rather more towards the bristle at the extensor edge, which happens to be a little less distal than its companions. The fourth bristle lies about the middle at the extensor edge of the segment, while the fifth lies slightly behind it and rather more inwards. The distal extensor surface of the fourth segment has six hairs of varying length; five of these are more or less grouped about the distal extremity, but the sixth lies farther back. The flexor surface has the usual two fine pores with accompanying diminutive hairs; one of these pores lies about the middle, the other one is nearly proximal.

The epimera are about as broad as long, a trifle over 0·7 mm. The lateral expansions are well developed, and the sutures between the epimera are very thick. This applies also to the posterior margins, which are rather broader than usual. The inner edge is nearly straight, having a clean-cut appearance. The width of the fourth pair is nearly equal throughout, the outer edge having sometimes a slight concavity near the gland pore, at other times it is slightly rounded. The point where the fourth pair of legs articulates with the epimera lies well in from the edge of the latter, so that about two-thirds of the first segment of the leg lies over the lateral expansion. The recess for the capitulum is about the same length as that for the genital area, but the latter widens out posteriorly.

The legs are of normal structure, and in the case of the third and fourth pairs may attain to, or even slightly exceed, the length of the body. The terminal segments of the second, third and fourth pairs are distinctly enlarged towards their extremities, but in the case of the corresponding segments of the first pair, if the enlargement exists, it is only weakly developed. None of the legs have swimming hairs.

The genital area is about 0·23 mm. in length and about 0·15 mm. in breadth, and extends for about a fourth of its length beyond the epimera. The lunate plates for muscle attachment which lie at each end of the genital area are fairly well developed. Along the inner edge of each of the valves, there are a number of hair pores. The acetabula are of normal form, and decrease slightly in size from the anterior pair to the posterior pair. The anus is only weakly chitinised, and is without the strong ring observable in some other species.

Externally, the sexes appear to be hardly distinguishable from one another.

Nymph.

Thor's observations on the nymph may be summarised as follows. The length ranges from 0·43 mm. to 0·55 mm., and the breadth from 0·35 mm. to 0·48 mm., so that the outline may vary from oval to nearly round. The colour is about that of the imago, though sometimes it may be brighter and more transparent. The skin is thin and ridged as in the imago. In the nymph, however, the ridges are smaller and not so abundant as

in the imago, the intervals being twice as great as in the latter. Any fine pores which may be present are extremely difficult to detect. The capitulum and the epimera resemble those of the adult form.

The palpi are about 0·22 mm. in length. The first segment is devoid of bristles. The second segment has one or two bristles distal and one about the middle of the extensor surface. The third segment has two rather long distal bristles, one at the extensor surface and the other about midway on the inner surface. The fourth segment has the usual two pores on the flexor surface.

The legs are about 0·40 mm. long for the first pair; 0·45 mm. for the second pair; 0·52 mm. for the third pair, and 0·68 mm. for the fourth pair. The terminal segments of the second, third and fourth pairs are like those of the adult. Swimming hairs are also wanting.

The provisional genital area has four acetabula surrounded by a chitinous ring, which is open towards the posterior and anteriorly is attached to the ligulate muscle attachment plate.

The larval stages are at present unknown.

Lebertia stigmatifera Sig Thor.
(Sub-gen. *Hexalebertia.*)

1900. *Lebertia stigmatifera* Sig Thor *Nyt. Mag. for Naturvid.*, xxxviii. 275–276, pl. xi. figs. 7–9.
1907. *Zool. Anz.*, xxxii. 150–157, figs. 87–90.

Lebertia stigmatifera was taken by Mr. Deeley in Worcestershire. It is here recorded as an addition to the fauna of the Britannic area, and is another link in the chain connecting the Scandinavian and British faunas. It belongs to the smaller species, a common size being about 0·7 mm., though extremes of 0·58 mm. to 1·05 mm. have been recorded.

The body is very nearly circular in outline, with the anterior margin rather flattened. The ground colour of the body is yellow, with large brown patches and the usual T-shaped yellow outline on the dorsum. The skin is comparatively thin, and is adorned with chitinous ridges, for the most part lying parallel to one another. The skin is very indistinctly porose; in the case of the more heavily chitinised parts, the common large pores are

to be found. The second and third segments of the palpi show the usual groups of fine pores, but in the fourth segment these gradually disappear towards its distal extremity.

The capitulum is of normal form, but rather small, as it does not quite take up the bay formed by the first pair of epimera. The posterior processes are short and thick. The mandibles are slender in structure, and about a quarter of a millimetre in length.

The palpi are about 0·4 mm. in length, and more slender than the first pair of legs. The fourth segment is distinctly longer than the third, and not quite so stout. The first segment has only one fine bristle on its extensor surface. The second segment is porose, and has four or five short bristles on its extensor surface. The characteristic bristle on the flexor surface is nearly straight and very slightly pectinate. It stands distinctly back from the distal edge. The third segment is also porose, and carries the characteristic of the sub-genus, namely, six long bristles on the inner surface of the segment. Of the three which are almost distal, two are close to the extensor surface. The fourth is not quite proximal, and is close to the extensor surface also. The remaining two are just a little posterior to the middle line—one is at the extensor surface and the other just inside of it. All the bristles are very long, some going beyond the distal end of the fourth segment. The fourth segment is weakly porose, and it should be noted that the two fine pores on the flexor surface are very close to one another and the accompanying hairs are very short. The rest of the fine hairs are grouped distally. The fifth segment is very short and tapered.

The epimera are of unusual size and possess an extension laterally and posteriorly which forms quite a characteristic feature, and is apparently most marked in the male. The fourth pair of epimera are so large as to include within the posterior margin the gland pore usually found outside. The articulation of the fourth pair of legs also lies well back from the lateral margin. The lateral expansion sometimes draws so far forward as to come close up to the second epimera. Just behind the third pair of legs, the expansion of the epimera encloses a large gland pore. The posterior inner edge of the fourth pair is nearly straight, making the corner almost right-angled. At each corner a short hair will be

observed. The anterior ends of the first and second pairs of epimera have each a moderately long hair. There are two or three short hairs behind the first segment of the third and fourth pairs of legs. The posterior extremities of the first pair of epimera end in a point about midway between the capitulum and the genital area. The second pair also ends in a point, but this is just at the genital area, where it is fused with the extremities of the third pair. The fourth pair is rather more rectangular, as the inner end is not broader than the outer. The epimera appear to be more fused together in the inner area. The sutures are broad, but not well defined.

The legs, which are devoid of swimming hairs, do not appear to possess any outstanding features of much moment. The distal end of the sixth segment is little, if any, stouter than the proximal end. The fourth pair of legs lies close up to the suture between the third and fourth pairs of epimera. The first segment has six spines on its extensor surface. The fifth segment has eight to eleven spines and the sixth segment five or six spines on the flexor surface. The claws are of normal form and size.

The genital area is small. In the female it extends very little beyond the epimera, and in the male not at all. The strong anterior sclerite is roughly triangular in shape. The posterior one is slender and arc shaped. The acetabula do not call for special comment. The posterior one is almost round and much smaller than the two anterior elongated ones. The valves have six to nine large pores along their outer edge, and along the inner edge there are a number of fine hair pores, ranging in the case of the female from twelve to fifteen and in the case of the male from nineteen to twenty-four.

The anus is surrounded by a strong outer chitinous ring.

Nymph.

So far the nymph has not been found among collections outside of Norway. The length appears to range from 0·50 to 0·63 mm., and the breadth 0·45 to 0·55 mm. The colour of the oval-shaped body is about that of the imago, while the skin is covered with fine chitinous parallel ridges.

The palpi are thick and about 0·22 mm. in length. The first segment has no bristles. The second has three on its extensor surface, of which one is distal. The third segment has three long

bristles on its inner side, one of these being nearly proximal and the other two almost distal, one of them being on the extensor surface and the other just inside of it. The fourth segment has three fine hairs distal on the extensor surface, and two fine pores close together on the flexor surface as in the imago.

The epimera are relatively short and broad. The area between the fourth pair of epimera is relatively wider than in the imago, but the fourth pair itself is much narrower, so that the gland pores lie well outside. The inner ends of the second pair are much broader, while the inner ends of the fourth pair are cut away very obliquely. The provisional genital area lies about half-way beyond the epimera. The outer ring is rather more oval than round and has only four minute pores. The sclerite between the genital area and epimera lies close up to the epimera. The anal ring is broad but not strong.

The legs have no swimming hairs, though a single long hair at the distal end of the fifth segment of the fourth pair of legs may be observed. The first segment of the fourth pair of legs differs from the corresponding segment in the nymphs of other sub-genera in the possession of three bristles on the extensor surface.

Lebertia trisetica Sig Thor.
(Sub-gen. *Hexalebertia.*)

1907. *Lebertia trisetica* Sig Thor. *Zool. Anz.*, xxxii. 157. fig. 91.

This form is allied to *L. stigmatifera*, but in comparison with it *trisetica* will be found to possess a thicker skin, the ridges on which are stronger and broader, with a greater tendency to branching. The intervals between the ridges are broader and minutely porose. So far as can be judged from preserved material, the colour would appear to be a reddish brown with a tinge of yellow.

In outline the body is oval or elliptical, with a length of about 0·9 mm. and a breadth of about 0·7 mm. Between the antenniform bristles the anterior margin is weakly concave.

The capitulum is about 0·21 mm. in length, with the lateral processes of moderate length and pointing in an antero-lateral direction.

The palpi are relatively slender, and are a little over 0·4 mm. in length, the individual segments being about 0·035, 0·102,

0·110, 0·143 and the terminal segment 0·034 mm. It will be observed that the third segment is a little longer than the second. The second and third segments are minutely porose, but the fourth is not. The distribution of bristles agrees fairly well with that of the allied species, but it is to be noted that those on the extensor surface of the first and second segments are stronger, while the bristle on the flexor surface of the second segment is very long and fine, and is curved upward. The striking characteristic of this species is to be noted slightly in advance of the middle of the flexor surface of the fourth segment in the shape of three fine pores with minute setae, whence the specific name of *trisetica*.

The epimera are strongly developed with thick sutures, and the inner posterior corners of the fourth pair almost rectangular. The genital area is about 0·22 mm. in length, with about one-fourth projecting posteriorly beyond the epimera. The inner edges of the valves have about twenty fine hairs distributed along their length. The acetabula are long, particularly the two anterior pairs.

The anus lies near the posterior body margin, and is surrounded by a stout ring. The gland pores on each side stand out conspicuously, as well as those at the posterior inner corner of the fourth pair of epimera.

The species was described from material taken in Surrey in 1896, and so far it has not been recorded from anywhere else.

DESCRIPTION OF PLATES.

Plate 33.

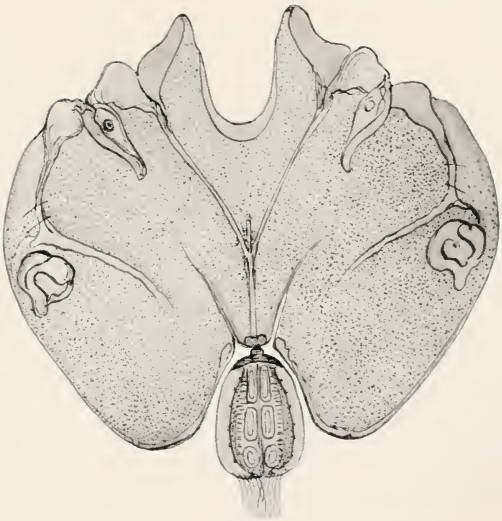
Fig. 1. *L. porosa.* Dorsal surface, × 22.
„ 2. *L. porosa.* Epimera of adult, × 66.
„ 3. *L. porosa.* Epimera of nymph, × 66.
„ 4. *L. porosa.* Larva, ventral surface, × 94.

Plate 34.

Fig. 1. *L. tau-insignita.* Ventral surface, × 26. (After Sig Thor.)
„ 2. *L. tau-insignita.* Genital area, × 80. (After Sig Thor.)
„ 3. *L. tau-insignita.* Inner side of left palp, × 133. (After Sig Thor.)

Fig. 4. *L. fimbriata.* Inner side of left palp, × 133. (After Sig Thor.)
„ 5. *L. fimbriata.* Fourth leg, × 60.
„ 6. *L. trisetica.* Dorsal surface, × 39.
„ 7. *L. trisetica.* Fourth leg, × 60.
„ 8. *L. trisetica.* Inner side of left palp, × 147. (After Sig Thor.)
„ 9. *L. trisetica.* Skin markings.
„ 10. *L. stigmatifera.* Inner side of left palp, × 147. (After Sig Thor.)
„ 11. *L. stigmatifera.* Genital area, × 66.
„ 12. *L. glabra.* Inner edge of right palp, × 147. (After Sig Thor.)
„ 13. *L. glabra.* Fourth leg, × 60.
„ 14. *L. porosa.* Fourth leg, × 60.
„ 15. *L. porosa.* Inner edge of right palp, × 117. (After Sig Thor.)

1



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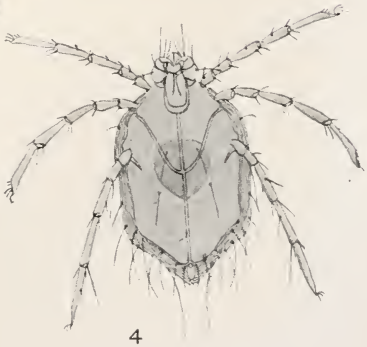
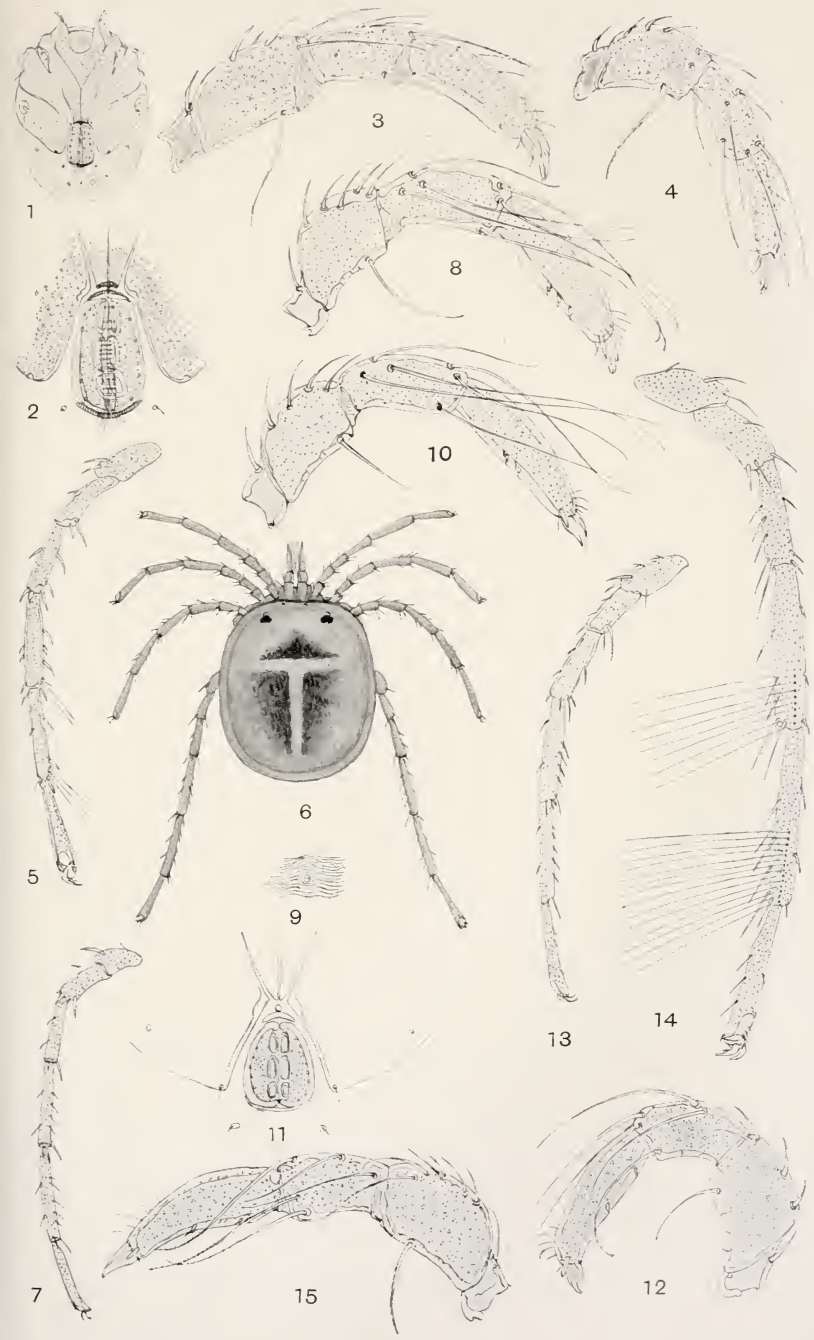


4

C. D. Soar, *del ad nat.*

The Genus *Lebertia*.



C. D. Soar, *del.*

The Genus *Lebertia*.

A "NEW" OBJECT GLASS BY ZEISS.

By J. W. Gordon.

(*Read March 23rd*, 1915.)

Figures 1 and 2.

In the November number of the Journal of the Club there is a paper by Mr. Nelson upon a new object glass by Zeiss. Of this object glass Mr. Nelson speaks in high praise, and no doubt it merits the encomium which he bestows upon it. Besides describing its performance, Mr. Nelson attributes entire novelty to the plan upon which this objective is constructed. That plan is the fitting of an oil-immersion front lens to a $\frac{1}{4}$-in. dry objective so that an oil-immersion objective is produced having a numerical aperture less than 1. Mr. Nelson certifies that, so far as his knowledge goes, this type of objective is quite new.

From the merit of Messrs. Zeiss in recognising the advantage to be secured by applying the oil-immersion front lens in this way, I do not at all wish to detract; but it is perhaps worth while to point out that the idea is not quite so new as Mr. Nelson supposes. So far back as July 1909, Messrs. R. & J. Beck produced and supplied to me a lens which was precisely of this type, and in design identical with this new lens of Zeiss, although in fact the oil-immersion front lens was applied to a $\frac{1}{2}$-in. dry objective. This lens I have had in constant use since then, and have exhibited it on various occasions. I am a little surprised to learn from Mr. Nelson's paper that I have not actually shown it to him. It was catalogued for exhibition at South Kensington at the time of the Optical Convention, and although there was a difficulty about the space, so that the lens itself was not actually set up there, the following description of it appears in the catalogue :

"The use of oil immersion has hitherto been confined to objectives of the 1/8th-in. and 1/12th-in. class under an impression, which proves to be mistaken, that oil immersion secures no particular advantages when applied to objectives of lower power. The model is a $\frac{1}{2}$-in. dry lens fitted with a supplementary lens of rather less than hemispherical angle, mounted so that the

centre of the sphere lies in the object. The spherical surface, therefore, produces no refraction, and its addition to the optical system involves no change in the correction of an objective adjusted for viewing an uncovered object. The abolition of the top surface of the cover glass by oiling on the supplementary front lens produces an increase of 50 per cent. in magnifying power, and a commensurate increase in light-gathering power. The catoptric haze produced by internal reflection from the front face of the permanent front lens sinks into comparative insignificance, and a $\frac{1}{2}$-in. dry lens is converted into a $\frac{1}{3}$-in. immersion system of much improved defining power."

Two things may be added to this description:

(1) The numerical aperture of this lens as it stands is 0·54.

(2) It was intended that this front lens should be made adaptable not only to the $\frac{1}{2}$-in. mentioned, but also to my $\frac{1}{4}$-in. objective, in which case it would have yielded exactly the combination which Mr. Nelson now describes. It was found, however, that the front lens was a little too thick for use with a $\frac{1}{4}$-in. objective, and consequently I have never been able to adapt it to a higher power than the $\frac{1}{2}$-in. The principle, however, upon which the construction is based is clearly set out in the extract above given from the catalogue of the Optical Convention, and if Messrs. Zeiss have given any attention to that document, it is obvious that for upwards of a twelve-month past they have had the benefit of the suggestion so made public. It is, of course, quite possible that the Jena House have paid no attention to the catalogue of the Optical Convention, but have worked out the theory of this new objective for themselves. Even if we suppose that they have profited by the publication which has been placed at their service, we must still concede to them the merit of being the first to turn to account a suggestion which has been equally at the disposal of our own British manufacturers.

While I am on this point I should like to communicate to the members of the Club a further development of this principle. In consequence of the failure of this lens, as I have explained, to serve the purpose as an oil-immersion front lens for my $\frac{1}{4}$-in. objective, I was led to provide myself with another, of which a sketch appears as fig. 1. It is adapted, as will be seen, to be mounted, not on the dry objective, but on the cover glass

of the specimen. A shallow brass ring enables the observer to move it about, and place it wherever he pleases on the specimen, so that it exactly covers the spot which he desires to examine. If, then, he places this specimen with this supplemental lens in position under his dry objective, he gets, in effect, precisely the combination which Mr. Nelson describes. It is to be observed that in this combination it is not necessary to make any corrections for colour or for spherical aberration, because if the lens is of the right thickness, so that the centre of its spherical surface coincides with the focal point, then the incident beam passes the air-glass surface of the lens without refraction. It passes, therefore, without aberration of any kind, and the dry lens is in exactly the same position as if it were applied to a dry object. In the case of a dry lens which is corrected for the cover glass this would, of course, be a dis-

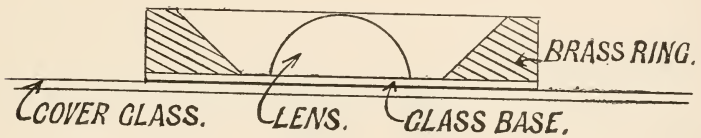


FIG. 1.

advantage, but a dry lens which is adapted to be used upon a dry object will give, under these conditions, a perfect image. That is, no doubt, the principle of construction of the Zeiss lens which Mr. Nelson describes.

To complete the description of this new adjunct: The brass ring is mounted upon a thin cover glass which, in its turn, carries the spherical lens cemented at its centre. Theoretically, of course, the lens and cover glass should be of the same glass, but in the case of my model I have used what I had ready to hand, without being punctilious upon this point.

Such a supplemental lens is for some purposes a very convenient adjunct to the ordinary microscope. In the first place, it puts the microscopist in possession of a system such as Mr. Nelson has described, at extremely small cost, for, of course, this appliance, consisting simply of a small brass ring, a cover glass, and an uncorrected spherical lens cemented together, can be produced at almost infinitesimal cost. It is then available for

use with any dry lens as required, of which it will increase the magnifying power by 50 per cent. with a proportionate increase in the amount of light collected, so that the enlarged image loses nothing in brightness. In this sense it increases the resolving power of the system, inasmuch as it increases the scale upon which all the details are shown.

That, however, is but the least part of its merit. If that were all it would only constitute a $\frac{1}{2}$-in. objective the equivalent of $\frac{1}{3}$ in.; $\frac{1}{4}$ in. the equivalent of $\frac{1}{6}$ in., and so on. What is very much more important is that it gets rid of the top light reflected down upon the surface of the object by the upper surface of the cover glass. It does not seem to be at all generally understood by microscopists how much resolving power is lost by reason of the fog produced by these reflections from the upper surface of

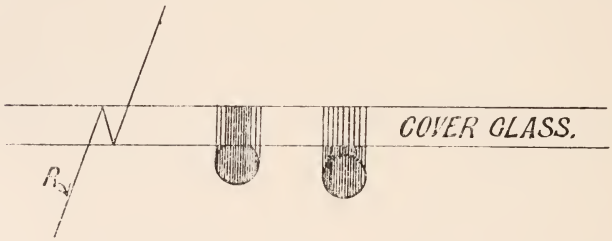


FIG. 2.

the cover glass. When we are examining an object like a diatom by transmitted light and producing, by means of that transmitted light, what the late Prof. Abbe used to call an *absorption* image—that is to say, an image in which the face presented to us by the object is seen in shadow—it is of first-rate importance that the shadows should not be illuminated by top light. A dry cover glass sends back upon the upper surface of the object a large amount of such top light, thereby obscuring the contrast by virtue of which the image is seen. Furthermore, if the object is not in actual optical contact with the glass, there is sure to be a reflecting surface between the glass and the mounting medium which is illuminated by this top light and again produces a brilliant haze through which the object has to be viewed. The diagram fig. 2 will serve to illustrate these points. Here a section is taken through the cover glass with

its upper surface dry and through the mounting medium and the specimen. The specimen is represented by two opaque objects, one in optical contact with the under surface of the cover glass, the other at some little distance below the surface, so that there is no optical contact in the second case. A line marked R indicates how light from the condenser is reflected downward from the upper surface of the cover glass, and then upward from its lower surface so as to produce a luminous haze overspreading the field except where optical contact between the specimen and the cover glass does away with the second reflection. It will be seen that the shadows produced by transmitted light are attenuated by this reflected light wherever the object does not come into optical contact with the cover glass. Similar considerations show that the light which is internally reflected from the upper surface of the front lens and again internally reflected from the lower surface of that front lens gives rise to a similar catoptric haze which is diffused over the whole field and serves therefore to attenuate the absorption image even of these objects which are in optical contact with the cover glass.

Now all this mischief, so far as it is due to internal reflections in the cover glass, is avoided by the use of a spherical lens cemented on to the cover glass, since by its means all such internal reflection is abolished. From this cause chiefly results the improved definition which gives to these immersion objectives of low angle their comparatively high resolving power.

Besides its extreme cheapness, this new form of immersion lens has the merit of serving as a finder. For example, an observer who wishes to keep a particular object—say a culture—under observation for a length of time can cement one of these supplementary lenses in place over the spot occupied by his specimen and put the specimen away in that condition. When next he goes to examine it he will find it without the least difficulty, for all that he has to do is to place his slide on the stage of his instrument with this cemented lens in the axis of collimation. It is possible, now that Messrs. Zeiss have discovered and advertised the value of low-power immersion objectives, that this very simple appliance may also find a manufacturer. Hitherto, I have not succeeded in interesting any of our manufacturers in it, possibly because the market price would necessarily be small. As against that consideration, however,

it may be pointed out that bacteriologists would probably find it worth their while to buy this piece of apparatus in considerable quantities, if it were to be had at a reasonable price, since it would very considerably facilitate their labour where a series of observations have to be made upon one given specimen of culture.

MICROSCOPICAL METHODS IN BRYOLOGICAL WORK.

By G. T. Harris.

(*Read March 23rd*, 1915.)

If any apology is needed for bringing before the Quekett Microscopical Club a subject that may only be of interest to a limited number of its members, I would find it in the fact that some years ago the Club had in Dr. Braithwaite a president whose supreme interest was bryological work. As long as bryology interests and attracts scientific workers will Dr. Braithwaite's name be held in honour, and his magnificent *British Moss Flora* rank with the splendid natural history monographs published during the nineteenth century.

It is easy to understand that mosses do not appeal very strongly to the microscopist *per se*, as the work to be done amongst them is more or less systematic; they offer no problems of resolution (that I know of), their development is quite well understood, and even an infatuated bryologist would be reluctant to advise an excursion amongst them in search of "display" objects. In spite of these drawbacks, however, it would be difficult to find a class better adapted to the requirements of the microscopist desirous of confining himself to some special group, and more especially to microscopists resident in large cities. Mosses may be gathered when opportunity permits, dried and stored for months, indeed years, and yet resume their original appearance when moistened previous to examination. Sufficient material for a whole winter's work can easily be collected during the annual vacation, and it is unnecessary to go to any particular district, unless of course special forms are required. Even an orchard is favourable ground, especially when the trees reach that desirable standard "old and crusted." Winter is *par excellence* the moss season, they then practically take over the country-side. There is no overgrowth of phanerogamous plants to conceal their presence; the hepatics may in some districts set up a rival claim for notice, but as many bryologists are also hepaticists this is not a disadvantage when collecting.

They are not in the least particular where they grow, any ineligible site will do for them. The only disturbing factor in the life of a moss that I am acquainted with is an east wind. They will stand all the indignities that man in the shape of an agricultural labourer can inflict upon them, but with an east wind they make no manner of compromise, they shrivel up; and how tightly a moss can screw itself up must be seen to be believed. Nothing more unlike the beautiful silky, pinnate stems of *Hypnum sericeum* can be imagined than the same stems showing their disgust with an east wind. It is obvious that moss collecting in an east wind is more or less of a failure.

The earlier bryologists relied mainly upon herbarium sheets for the preservation of their specimens, and, while admitting that the herbarium is an essential in systematic work, I incline to the opinion that insufficient attention has been paid to the formation of what may be described as the micro-herbarium. Herbarium sheets at the best can give only the general habit of the plant, and, indeed, in a very large number of species even this is so poorly preserved as to be practically valueless. The specific differences are dependent upon microscopic structure, and either mounted slides or fresh material must be referred to before the species can be named with certainty. Thirty years ago specific distinctions were largely dependent upon general habit and such simple low-power observations as the presence or absence of the so-called "nerve," its length, and the nature of the leaf margin. Hence we find Berkeley contenting himself with the brief remark that an objective of one-third of an inch is the most convenient for examining the leaves, while low powers are sufficient for the determination of genera and species. Since then bryology has become more and more a microscopical study, and Berkeley would probably have been aghast had he been told that almost in his own day specific determination would be to a considerable extent a matter of cell-measurement. Even Braithwaite kept outside the region of the micron. It can be seen that the modern bryologist has of necessity to be at least a fairly competent microscopist, and that the time has come when the carefully displayed sheets of the moss herbarium mean very little to the critical systematist. No bryologist in the present day would care to decide upon the specific names of a large number of our British mosses from an examination in the field, even with the

aid of a good lens. The inevitable result is that the micro-herbarium becomes increasingly more important to the systematic bryologist.

The collection of slides the Quekett Microscopical Club has done me the honour of accepting is fairly representative of the kind of slide useful to the bryologist, although I have, in the hope of proselytising amongst the members, made it more popular than would otherwise have been the case. There is no question of making attractive mounts with the bryologist, even if mosses lent themselves to such a proceeding. By the time the modern student of mosses has decided whether some moss is a sub-species, variety, form, or hybrid of a certain species, he is usually beyond the ambition of making an attractive mount of it, and merely desires to see it safely under a cover-glass for future reference. From the student's point of view the collection would undoubtedly have been of far greater usefulness had it consisted of series showing varietal differences in such difficult forms as exist amongst the Harpidioid Hypna, but the general interest of such a collection would have been *nil*. The casual excursionist into the moss world is more concerned with general impressions than varietal distinctions, and the microscopist who values his wholesome outlook on Nature will leave such sections as the Harpidioid Hypna to its creators.

To the confirmed microscopist I fear the class Musci can never be very attractive, as it is difficult, except in a limited degree, to obtain clean, immaculate slides. The cleaning of such species as *Fissidens exilis*, *Pottia minutula*, etc., which not only live on tenacious clay formations, but succeed in covering themselves entirely with it, is appalling if conscientiously carried out, and usually quite fruitless, as by the time the clay has been removed the specimen is in fragments and not worth mounting. Hence cleanliness is next to uselessness in bryological work, and a really useful collection of moss slides occupies a debatable position between the geological and botanical kingdoms. I mention this in case your Hon. Curator is puzzled as to which kingdom some of the slides are intended to represent. A considerable amount of soil usually adhering to the specimens may be got rid of by prolonged soaking, repeatedly changing the water, and very considerable help is got by strongly acidulating the water with hydrochloric acid; especially is this the case in calcareous

districts. Boiling the specimen may help matters if it is thought the moss is robust enough to stand the treatment, and some species certainly will. But the application of a stiff camel-hair pencil is always necessary to dislodge the particles that adhere in spite of all soaking and boiling. And when all has been done there is always the victorious residuum to jibe at one's efforts. Many species are so fragile that any attempt at cleaning beyond the most superficial seriously injures the specimen; such is the case with those species having highly papillose leaves—in fact such leaves are rarely found perfect, so easily do the papillose cells break away from each other. It is obvious that the question of cleaning the material is a serious tax on the time of the bryologist, and that there really is a valid excuse for his mounts not being the immaculate objects usually achieved by the microscopist.

Another cause contributing to indifference in bryologists' slides is the necessity that exists for accomplishing a considerable amount of work in a short time. The busy systematist spends so much time in the examination and naming of his specimens that the margin of time available for the preparation and mounting of slides to illustrate his species is too meagre to allow of deliberate and painstaking care, hence a slide which would be better for remounting is allowed to pass if it shows clearly the desirable features. It is without doubt the need for the minimum of trouble in mounting that has caused the majority of bryologists to rely on glycerine jelly for obtaining their mounts. At least I have ascertained that many quite eminent workers do rely on this medium, and from what I have heard I fear to their undoing. Some years ago, by great industry, I amassed a considerable collection of slides illustrating the Hypnaceae, spending the leisure hours of an entire winter in doing so, and in twelve months' time I had the pleasant experience of washing them off, as slides so illustrative of lacunae and every phase of cavity were of no use to me. As I had slides mounted in glycerine jelly perfectly good after a lapse of six years, it was obvious that it was not necessarily an unreliable medium, and as I believe it to be the most convenient medium for general work in bryology I give the following hints to novices for what they may be worth. In the first place, the jelly itself must not be made with a hard gelatine. I used Drescher's emulsion gelatine,

which is an extremely clear but hard gelatine, and this was the principle cause of my disaster. The jelly must contain a good proportion of glycerine. Kaiser's formula appears to be a very good one if home preparation is in view, as it does not set hard. I have slides six years old mounted with it which have suffered no deterioration. The object to be mounted should be soaked for a considerable time in equal parts of glycerine and water (in my own work they always have twenty-four hours); unless the structure of the object is thoroughly permeated with the dilute glycerine, lacunae are sure to develop by subsequent absorption. My own experience leads me to the conclusion that a point of great importance in using glycerine jelly so as to ensure reliable mounts, is to avoid mounting the object with the jelly at a high temperature; it should be used at just about the melting-point. If the temperature is high, subsequent contraction is considerable and cavities around the object are not unlikely to make an appearance later on.

Another point where many mounters err, especially bryologists, is in applying considerable pressure to the cover-glass until the jelly has set, thus pressing out the bulk of the jelly and leaving only a thin film between the slip and cover-glass. It is very nice to have a leaf mounted perfectly flat so that the cells can be studied from apex to base without focusing down through the convexity of the leaf; but such slides are seldom permanent. The amount of jelly should be sufficient to cover the object; and it is easy, when constantly using jelly, to guess just about the amount that will cover the object and spread to the edge of the cover-glass when it is placed in position. When the jelly has thoroughly set, if any has escaped beyond the edge of the cover-glass it should be washed away. Personally, I lay the slide aside for about twenty-four hours after mounting, then give it a good scrubbing with a moderately stiff tooth brush under a jet of water. This frees it from all glycerine outside the cover. The slide is then ringed with a plain solution of good hard gelatine, the strength of the solution being immaterial so long as it is not a weak one. When this has set, which it will do quite quickly, it is brushed over with a 10 per cent. solution of chrome alum. At first I used formalin, but found that its indurating action was so great that the ring of gelatine split and peeled off. Chrome alum toughens rather than hardens the gelatine. In its present

state the slide is perfectly safe for months, and may be finished at some convenient time subsequently. The finishing consists in ringing with old gold size, coat after coat, with intervals to allow for hardening.

I have been most desirous of making glycerine jelly mounting a reliable process, owing to its great usefulness in rapidly mounting reference slides of leaves and small species of moss. Unfortunately I have received several bad shocks in my own work, and in reports from other bryologists, and I must frankly confess to a grave misgiving in asking the Quekett Microscopical Club to accept slides mounted in this medium. Only the fact that I believe some of the principal pitfalls to have been traced and overcome has permitted me to include any at all. Certainly for a long time past now I have been immune from my former perennial crop of lacunae and cavities. In all cases the date of preparation has been marked on the slides, and if they are not an example at least they will be a warning.

Unless the object is of an appreciable thickness the film of jelly necessary to cover it will not be so thick as to need any support; but if some species, or portions of large species, are mounted with their capsules the amount of jelly necessary may need some support at the edge to keep the cover-glass even. A convenient way of doing this is to use a ring of silver wire about the diameter of the cover-glass and of a thickness proportioned to the object. Practically a thickness of 23 B.W.G. meets all needs, and I confine myself to this thickness. Silvered wire is easily and quickly prepared by taking copper wire of the desired thickness, thoroughly cleaning it from all grease, and immersing it in silver cyanide solution. It can then be kept on a reel, and cut off as required. The ring needs no attaching to the slip, as the gelatine holds it in position; but it may be slightly flattened by hammering.

Farrant's medium probably comes next to glycerine jelly in usefulness to the bryologist; it is very convenient to use, and, of course, allows of great deliberation in arranging the object, removing such undesirable matter as can be removed, and it gives good transparency to incrassate cells. For peristomes, which require to be examined by transmitted light, it is excellent, though the fragile endostomes of some species are made too transparent by it.

When my loss of the twelve dozen type slides of the Hypnaceae shook my faith in glycerine jelly I made experiments in search of a substitute, and found an extremely good one in copper acetate combined with glycerine. The formula is given in Squire's *Methods and Formulae*, but is not referred to any author. It has the advantage of being also a fixing agent:

Copper acetate	0·2 gramme.
Mercury chloride	0·4 ,,
Acetic acid	0·2 c.c.
Glycerine	25·0 ,,
Distilled water	25·0 ,,

This gives a certain amount of transparency to the cellular structure of the leaves, but it naturally imposes much more labour on the mounter, and is better suited to the microscopist who merely wants mosses for general interest.

A large number of mosses are so minute that they are quite useless as herbarium specimens, and the only satisfactory way is to possess them mounted as microscopical slides; such species are *Fissidens exilis*, *F. pusillus*, *F. viridulus*, the majority of the species of the genera Pottia, Ephemerum, Pleuridium, etc. The leaves of these small species are usually very transparent and do not require to be made additionally so by glycerine, even when dilute. Acetate of potash is an admirable mountant for such forms, especially when containing a trace of copper acetate. The following formula has given me satisfaction, it is based on the one Prof. G. S. West recommended for algae:

Copper acetate	0·05 gramme.
Potassium acetate	1·0 ,,
Water	25·0 c.c.

Formalin, $2\frac{1}{2}$ per cent. solution, may also be used for these minute, transparent species, but in slides that have been mounted a number of years I have noticed that the formol sometimes precipitates, so that I have been reluctant to use it to any considerable extent. On the other hand, many slides in formol appear to have kept perfectly, so that much may depend on the sample of formol used.

With leaves of such species as *Andrea Rothii*, which are extremely dark in colour and of leathery consistency, it is im-

possible to examine the structure satisfactorily in its normal condition, and they are best treated in a solution of caustic soda or potash, as recommended by Dr. Braithwaite. This renders them flaccid and defines the cell structure. They should, of course, be washed well before mounting, and glycerine in some form is desirable with them as with all dense-leaved species. The species of Andreaea are typical of the difficulties that confront the bryologist in attempting to get satisfactory permanent mounts. They are deep red or black-brown in colour, very dense and cartilaginous in texture, extremely brittle and abominably dirty. It may be remarked that the colour of moss leaves, which is usually some shade of green, is a matter of minor importance to the mounter, hence it can be left out of consideration in choosing a medium for mounting. The bryologist mounts the leaves altogether for shape and cell-form, as upon these depend in a great measure the determination of the species. Usually the colour disappears in the course of a few months, but curiously enough in the same medium the green colour of closely allied species will remain fairly good. Very often saprophytic algae will retain their colour perfectly, while the moss has altogether parted with it.

There appears to be no necessity for "fixing" the specimens before mounting; but with leaves of comparatively delicate structure it is often advantageous to do so unless the mounting medium contains a fixing agent, and I have had very good results with the complanate branches of such species as *Plagiothecium elegans* and *Plagiothecium depressum* by fixing them in picric acid before mounting in glycerine jelly, the picric being washed out previous to mounting. With such a species as *Plagiothecium depressum*, which bears very characteristic bunches of deciduous flagellae on its branches, every care has to be exercised to avoid detaching the flagellae, whose particular mission it is to become detached with the slightest provocation. Such is the case with many species of *Tortula*, the leaves of which bear characteristic gemmae. The extremely beautiful bunches of gemmae at the apices of *Ulota phyllantha*, and the scattered gemmae on the leaves of *Orthotrichum Lyellii*, are other instances. It is only the novice who will attempt to "clean" such leaves; the confirmed bryologist is too thankful to get the leaves mounted with the appendages adhering to worry over a small amount of adventitious matter.

The air contained in the cork-like cells of *Leucobryum glaucum*, and other species with inflated cells, is often very difficult to discharge. Boiling gets rid of a certain amount, especially if the leaves are left in the de-aerated water for a day or two, with reboiling at intervals. Obstinate cases require exhausting with an air pump. The leaves of the Sphagnaceae are especially difficult if the moss is once allowed to become thoroughly dry and the cells filled with air. I make a point of mounting these as soon as collected, or, at any rate, of keeping the stems saturated with water until I can attend to them. Bryologists attach very great importance to the basal areolation, and it is necessary that the leaves should come away from the stem quite complete and uninjured, but it is not at all a simple matter to detach the leaves from the stems previous to mounting them. With strongly decurrent leaves, such as exist in *Mnium stellare* and in some Hypna, it is almost impossible to obtain perfect specimens, and it is better to remove several of the adjacent leaves, and mount a portion of the stem with the leaf in situ. Generally, the most satisfactory way of removing a leaf is to take hold of the apex with a fine pair of forceps, and, holding the branch with another pair, very gradually to strip the leaf from the stem in a downward direction. Mosses with filiform stems and distant leaves such as *Amblystegium serpens*, can be studied by mounting the stem with the leaves attached. The strongly falcate and circinnate leaves of Harpidioid Hypna are very unmanageable, and I usually strip a considerable number of leaves from the stem, and mount the lot as a "spread" slide, trusting largely to luck to arrange some of them in a suitable position for examination. This is obviously a reckless method, but it answers very well.

A certain amount of section cutting is necessary to the systematic bryologist, apart from any histological investigation. The leaves of the Polytrichaceae, for instance, have the surface covered with longitudinal lamellae consisting of rows of upright moniliform filaments. Prof. Lindberg was the first to point out that these formed a valuable aid in diagnosing the different species, as the transverse number and shape of the terminal cell differ in each species. The only way in which they can be satisfactorily examined is by means of a transverse section.

The section Aloidea of the Tortulaceae also has lamelliferous leaves, of which sections are necessary. The quickest and

simplest way is to cut the sections in an ether-freezing microtome, and extremely thin sections are not demanded, but as the sections must be cut at right angles to the axis of the leaf, some care in orientating the leaf has to be taken. Sections of stems are also required in determining species of Sphagnaceae, but these are, of course, a simple matter.

In dealing with the capsule of the moss two methods of mounting may be employed for the study of the peristome. It may be mounted dry as an opaque object, or in some medium as a transparent one. Mounted dry and illuminated with reflected light the peristome is the only concession the moss world makes to spectacular effect. For purposes of study, however, the limitations of this method are great, and the student is forced to adopt transparent mounting. At the same time dry mounts of some peristomes are quite useful to the bryologist in getting at the general appearance ; the sulcae of the Orthotrichum capsule and the cilia of its endostome are quickly and satisfactorily exhibited as an opaque object under the binocular microscope. For anything like detailed study, however, the peristome must be mounted as a transparent object. A good deal depends upon getting the capsule in the right condition. It should be quite ripe, so that the touch of a needle at the junction of the operculum with the capsule will liberate the lid and enable the peristome to unfold without injury. If the lid has to be forced away some of the teeth of the peristome usually go with it. To prepare it for mounting, the capsule may be severed transversely about the middle, then a longitudinal slit made through the annular ring and that portion of the capsule wall adhering ; this permits of the peristome being spread out flat. The spores require washing away, though it is an advantage if some of them adhere to the teeth, as they often afford valuable specific characters. If the capsule has already shed its spores when gathered, but is not dilapidated, it is often in a very favourable condition for mounting, and in those mosses with a double peristome the endostome can often be detached and mounted separately from the exostome ; this enables the cilia so often present in double peristomes to be studied to the best advantage. When the cut peristome has been laid flat and judiciously cleaned it should be subjected to a cover slip and spring clip for a day or two, glycerine and water being run under by capillary attraction. The annular cells are usually

so elastic that some difficulty is found in keeping the peristome flat when it is mounted unless pressure has been previously applied. Glycerine jelly or Farrant's medium are the most convenient mountants. There is really no particular reason why the peristome should be mounted in its entirety, as a sector of it serves all useful purposes and is very much more easily managed ; that is to say, there is no additional knowledge gained by mounting the whole thirty-two teeth of a double peristome when a sector embracing four each of the outer and inner teeth will enable all structural details to be made out. The tubular teeth of the Tortulaceae can only be mounted *en bloc* ; the basal membrane is the point of interest, and so long as this can be clearly made out the rest does not matter.

In some species the teeth of the peristome are extremely fragile, and it is rarely possible to get satisfactory mounts of them if one relies on finding a perfect specimen in a chance gathering. I believe the only way is to bring home unripe specimens and carefully ripen them under observation, so that the capsule can be mounted as soon as the ripe operculum falls.

The capsules of the Orthotrichaceae bear very important characters in the presence of stomatic cells. These are of two forms ; in the one they are seated in the cuticle only and are "superficial," in the other they are buried in the wall of the capsule and are "immersed." To get a good view of them the capsule is slit up and the spore sac removed. The capsule is then spread out on a slide, cuticular side uppermost, and mounted in glycerine jelly. The stomata are said usually to be found in the lower half of the capsule, and they are certainly always found there in the books ; but occasionally nature seems to ignore her own boundaries, for I have seen them scattered here and there over the capsule.

As I have previously stated, a student's collection of slides would be no incentive whatever to any one to take up the study of mosses. At the same time I can imagine no more valuable collection than a reference series of slides of closely allied species, and species subject to wide variation. The determination of species and varieties in the moss flora has become a matter of extreme difficulty, thanks to the efforts of specialists in various groups, and even an advanced worker is glad of anything that looks like finality. Fifty years ago English bryologists considered themselves well served with ten species of Sphagna, the

separation of which was no great strain on one's mental powers. At the present time it is useless to touch the group unless you are prepared to distinguish between at least forty species, with an average of four varieties each. Of *Sphagnum acutifolium* alone Warnstorf describes sixty varieties, and I believe that very few even critical bryologists would care to rely on their own diagnosis of them. It will be seen from this how valuable an authenticated collection of slides would be to the bewildered student.

It will perhaps be desirable to state that the nomenclature adopted in naming the slides is that of the second edition of Dixon's *Student's Handbook of British Mosses*. I believe that Dr. Braithwaite's magnificent monograph is in the library of the Quekett Microscopical Club, and my first intention was to take that as my guide; but Dixon's Handbook is now so generally used, and is so compact, that it would probably be the book selected by any one who decided to take up the study of the mosses; and I may say that the critical comparisons in it between closely allied species are extremely useful to the student working alone.

Notes on a Collection of Slides of Mosses.

Polytrichum formosum.

Sections of a leaf cut to show the jointed appendages that constitute the lamellae. These appendages are of great use in determining the species, as the form of the terminal cell, the number of cells in each appendage, and the average number of appendages in the transverse section differ with the species.

Ceratodon purpureus.

A common moss in dry woods, on sandy banks, etc., but also a very polymorphous moss. In spite of considerable leaf variation, however, a distinct and constant feature is the recurved margin, becoming plane immediately below the apex, which is usually toothed. The characteristic annulus is well shown in the slide.

Dicranum majus.

A fine moss usually occurring in mountainous woods. The common and variable *Dicranum scoparium* in some of its forms, which are chiefly barren, approaches it very closely. *Dicranum majus*, however, bears a multiple number (2–5) of setae from one perichaetium. Both species belong to the section Eu-Dicranum, which is characterised by the leaves having lateral pores connecting the cells in the lower part of the leaf.

Leucobryum glaucum.

An interesting moss, the leaves of which are well worth careful examination. The chlorophyll cells are masked by an outer layer of hyaline, inflated corky cells communicating by pores. The greater portion of the leaf is composed of the nerve. Cardot has monographed the genus, see his *Recherches Anatomiques sur les Leucobryacées.* It is a not uncommon moss on dry, turfy ground, but the fruit is very rare, and according to my experience found chiefly when the moss grows in quite damp localities. A curious state of the moss occurs in dry woods in which it forms small rounded cushions, quite detached from the ground, and

easily transported by strong winds or contact with moving objects. The leaves are easily detached and often bear at their tips tufts of radicles which give rise to new plants.

Fissidens exilis.

One of the smallest species of the Fissidentaceae and readily known by its non-bordered leaves.

Fissidens viridulus.

Known from the preceding by its leaves having a narrow border to them, but the variety *Lylei* has the border wanting except on the sheathing laminae.

Fissidens algarvicus.

I am able to include a specimen of this new British moss through the kindness of Mr. G. B. Savery, its discoverer in England. It comes near *Fissidens pusillus*, and so far has only been found in two localities, Silverton in Devonshire, where Mr. Savery first discovered it, and near Cheltenham. It is characterised by its narrow acute leaves with rather strong and narrow border.

Fissidens bryoides.

An extremely common and variable species, the *forma inconstans* was originally a separate species, but is now generally considered to be merely a "form" of *F. bryoides*. As will be seen from the two slides, the difference is considerable in general appearance, and I have found the form *inconstans* to be little subject to variation from widely different localities.

Rhacomitrium lanuginosum.

This is the largest British species of the Grimmiaceae, and often covers immense tracts of mountain moorland with great masses. The hyaline and papillose serrated leaves are very beautiful.

Hedwigia ciliata.

Another inhabitant of dry, rocky localities, with, as is usually the case with such mosses, hyaline apices to its leaves. The

perichaetial bracts are ciliated, as may be seen in the slide, whence the specific name.

Pottia lanceolata.

The Pottias are usually without peristomes, but the present species is a notable exception, in that it possesses a highly developed one.

Pottia truncatula.

A gymnostomous form readily known by the truncate capsule with wide mouth, and by the columella being attached to the lid and falling with it.

Barbula lurida.

This is essentially a calcareous-loving species, and is considered very rare in fruit. The peristome is very fragile, and it is difficult to obtain good specimens.

Ulota phyllantha.

Readily known by the clusters of brown gemmae borne at the apices of the leaves. The fruit is extremely rare, and has only been found once or twice in England.

Orthotrichum Lyellii.

This also may be readily known by the brown gemmae, which in this species are scattered generally over the surface of the leaves. It rarely fruits.

Orthotrichum diaphanum.

The capsule wall of this species shows the "immersed" stomata, and should be compared with the slide of *Orthotrichum affine*, which shows "superficial" stomata. The two forms are very useful in diagnosing the species of this difficult genus. The outer "superficial" cells are well shown in the slide, and the reniform "guard" cells may be brought into view by focusing down through the superficial cells.

Brachythecium rutabulum.

One of the commonest and most variable of the British mosses. The type is not difficult to recognise, but the varieties with very acuminate leaves are difficult to determine, especially when barren, as they often are.

Hypnum cupressiforme.

This again is a very variable form, and its varieties differ widely from the type. The var. *resupinatus* has had specific rank from many authorities, but it certainly differs no more from the type than does the var. *filiforme*.

PROCEEDINGS

OF THE

QUEKETT MICROSCOPICAL CLUB.

At the 501st Ordinary Meeting of the Club, held on October 27th, 1914, the Vice-President, Mr. D. J. Scourfield, F.Z.S., F.R.M.S., in the chair, the minutes of the meeting held on June 23nd were read and confirmed.

Messrs. Samuel Ernest Loxton and W. Beattie were balloted for and duly elected members of the Club.

The list of donations to the Club was read, and the thanks of the members voted to the donors.

Two series of Dr. Sigmund's histological preparations with descriptions and sixty-one slides were added to the Cabinet.

The Chairman read a letter conveying the information of the death of Dr. Arthur Mead Edwards, of Newark, New Jersey, U.S.A., which took place on September 13th, 1914. Dr. Edwards was the oldest honorary member, having been elected in January 1868. He was at that time President of the American Microscopical Society of New York. At his death he was seventy-eight years of age. His chief microscopic work was in the study of the Diatomaceae. His communications are still remembered by some of the older members.

The report from the Club's delegate—Mr. C. F. Rousselet, F.R.M.S.—to the conference of the delegates of the corresponding societies of the British Association at Havre was read by the Secretary. The Congress began on Monday, July 27th. Mons. A. Gautier, the President, welcomed the members, and delivered an address. On behalf of the English members, Sir W. Ramsay addressed the meeting in French. On Tuesday there was a conference of delegates in the Town Hall. Sectional meetings took place on that day and on Wednesday. On Thursday, the 30th, an excursion up the Seine as far as Rouen, visiting various historical places on the way, was made. On Friday meetings were held, but, owing to the threatening political outlook, were poorly attended. On Saturday, August 1st, the Government decree of general mobilisation was given, and the

conference, which had been much hampered by the political unrest, hurriedly broke up. The Chairman tendered the Club's thanks to Mr. Rousselet for his report, and congratulated him on his safe return.

A paper by Mr. A. A. C. Eliot Merlin, F.R.M.S., was read (in part) on "The Minimum Visible." It commenced: "I have read with great interest and profit our President's address on 'Organisms and Origins.' The subject is one that must fascinate every microscopist, whatever his line of research. In the address the point was raised respecting the minimum visible, it being stated that 'it seems impossible to obtain any precise information as to the size of the smallest particles that can be seen with the microscope.' Now, setting aside the ultra-microscope, as our knowledge is very exact and definite indeed on this subject, it may prove of interest to deal with the question at some length. As a matter of fact, when a particle properly illuminated is just visible with a given objective, if the aperture be cut down by means of an iris diaphragm, placed above the back lens, so that the particle just ceases to be visible, and the N.A. to which the objective has been reduced is measured, then the dimensions of the particle can be exactly ascertained from the antipoint table published by Mr. Nelson in the *Journal of the Royal Microscopical Society*. This antipoint table should prove invaluable when accurate and minute measurements are necessary."

A recent paper by Mr. N. E. Brown, A.L.S., "Some Notes on the Structure of Diatoms," was referred to, in which Mr. Brown stated that he had seen pores on the surface of certain diatoms which he estimated at 1/200,000th of an inch in diameter. Mr. Merlin, examining some of the diatoms under a very perfect $\frac{1}{12}$ apochromat, N.A. 1·4, employed with a magnification of 4,200, readily distinguished these pores, but in them so resolved believed he immediately recognised Dr. Royston Pigott's "dark eidolic dots of interference."

In speaking on the subject of Mr. Merlin's paper, Mr. N. E. Brown said: "If I understand Mr. Merlin correctly, the two points in it which call for any remark from myself are that the structures I have conceived to be pores were discovered by Dr. Royston Pigott many years ago, and considered by him due to interference. I much regret that I have not read Dr. Royston Pigott's paper, or I should have referred to it in my

recent notes. But I certainly cannot agree that these structures are myths without substance. I still maintain that they are very real structures. I take it that if they were interference figures, they could only be formed when the dots from which they are supposed to emanate are regularly placed, equally spaced and of the same size, also that under different conditions of illumination or the shifting of the mirror they would alter their position or form. But this is by no means the case. In most diatoms the dots are regular in position and size, but on some portions of the shell of *Nitzschia scalaris* regular rows of small dots and diverging rows of much larger dots may be found side by side, and some of the dots in the diverging rows are often quite irregularly placed, yet the structures I suppose to be pores are regularly placed along the middle of the space between the rows in each case, or, where very widely diverging, the row of pore-structures forks. Also they do not shift their position under varying conditions of illumination; they can be seen alike and in the same position with axial illumination and a full cone or small cone of light, with annular illumination, with oblique illumination in one azimuth arranged either parallel with or transverse to the rows of dots, with either a chromatic Powell and Lealand or an Abbe, or an achromatic Powell and Lealand substage condenser. Surely identical myths could not be produced under all these conditions."

Mr. Ainslie, while pointing out the impossibility of any detailed criticism until opportunity had been obtained for carefully going through the statements, remarked that size alone by no means determined the limits of visibility: the quality of an object, its opacity or transparency, and other factors, would affect the matter. He gave some instances where structures had been distinctly seen which were far smaller than what is scientifically considered the minimum required for visibility. On the proposal of the Chairman, a very hearty vote of thanks to Mr. Merlin for his valuable communication was recorded.

Mr. Rousselet exhibited under microscopes two species of African Volvox. These had a somewhat remarkable history. In October 1910 a paper by Prof. G. S. West, of Birmingham University, was read, in which two new species of Volvox from Africa are described. One, *V. Africanus*, had been collected by Mr. R. T. Leiper, of the Egyptian Government Survey, from the north part

of Lake Albert Nyanza. The other, *V. Rousseleti* (named in honour of its discoverer), was obtained by Mr. C. F. Rousselet on the occasion of the visit of the British Association to South Africa in 1905, from a pool formed by the Gwaai River, near the railway-station. In both cases only asexual vegetative individuals were acquired, with the result that a complete description could not be given. In 1913 Mr. Rousselet received from Dr. Jakubski, of the Zoological Institute of Lemberg University, some tubes containing plankton material collected in German East Africa. In two of these tubes, among other objects, Mr. Rousselet was surprised to come across numerous colonies of Volvox, which he at once recognised as the same two species already described by Prof. West. Fortunately, in this case, both species were present in their various sexual stages, with androgonidia and oospores, as well as the vegetative colonies. It will, therefore, now be possible to complete the description of both species. A tragic note is given to the episode by the fact that Mr. Rousselet returned, as requested, the tubes and specimens to Prof. Jakubski at Lemberg early in July; but owing to the war and the occupation of Lemberg by the Russian Army soon after they should have arrived, he has not been able to ascertain whether they safely reached their destination, or what has become of them, or of the correspondent to whom they were addressed. A vote of thanks to Mr. Rousselet for his interesting communication was carried by acclamation.

Mr. W. E. Watson Baker exhibited under a microscope a mounted specimen of the egg of the Anopheles mosquito and a very young larva of the same. The organism is rarely found in these conditions; but the Secretary mentioned that on two occasions last year, at excursions of the Club, he had obtained specimens of nearly mature larvae. In one of the instances he had been able to feed the creature—they devour some of the smaller algae—till it pupated, and finally the perfect insect emerged. The meeting thanked Mr. Watson Baker for his beautiful exhibit.

At the 502nd Ordinary Meeting of the Club, held on November 24th, the President, Prof. Arthur Dendy, D.Sc., F.R.S., in the chair, the minutes of the meeting held on October 27th were read and confirmed.

Messrs. Walter Adams, George Clarendon Hamilton, F. Reardon Brokenshire, W. Ludlow Haynes, Alexander McTavish, W. B. Tindall, Henry Jewell and the Rev. John Bruce Williams were balloted for and duly elected members of the Club.

The list of donations to the Club was read, and the thanks of the members voted to the donors.

The President called upon the meeting to pass a resolution expressing the members' deep regret at the loss they had sustained by the death of Dr. M. C. Cooke, M.A., LL.D., A.L.S., which occurred on November 12th at his residence in Southsea.

Dr. Mordecai Cubitt Cooke was born July 12th, 1825, at the village of Horning, in Norfolk. From an early age dependent upon his own resources, he was in turn employed as draper's assistant, teacher in a National school, and lawyer's clerk. As an assistant in the Indian Museum he at last found congenial occupation, and on the abolition of that institution he spent some time at South Kensington Museum. He afterwards joined the Herbarium at the Royal Botanical Gardens, Kew, and was for twelve years (1880–1892) in charge of the Cryptogamic Department. In 1892 he retired. During this time he incorporated his own herbarium, which contained 46,000 specimens, with the existing collection at Kew, as well as the collection of fungi presented to Kew by the Rev. M. J. Berkeley. His figures of fungi, mostly coloured, and numbering 25,000 plates, are also at Kew.

His first important work was the *Handbook of British Fungi* (1871), followed by *Mycographia*, *Handbook of Australian Fungi*, and *Illustrations of British Fungi* (with 1,200 coloured plates). He was editor of Hardwicke's *Science Gossip* from its beginning in 1865 until December 1871. Dr. Cooke, the "father of the Club," was one of the eleven members who attended the preliminary meeting of the Q.M.C., held on June 14th, 1865, and he was elected one of its first vice-presidents. He was president in 1882 and 1883, and was elected an honorary member in 1893.

Mr. J. Grundy introduced and explained the great advantages of a micrometric table by Mr. E. M. Nelson. The table is similar to logarithm tables, the cross marginal numbers being M and O respectively. The table gives the value of $O \times 100/M$. M is the reading of one division of a stage micrometer in the divisions of the eyepiece micrometer. O is the reading of the object to be

measured in the divisions of the eyepiece micrometer. To find the size, take in the table on the M column the number representing the reading, and the number in that line vertically below the reading in the O line will be the size of the object in microns. Example: 0·1 mm. of stage micrometer spans 28 divisions of the eyepiece micrometer. M is then 28. An object measures 19 divisions of the eyepiece micrometer. O is then 19. Utilising the table, the size will be found at once—viz. 68 μ. Should the measured division or unit of the stage micrometer be 0·01 mm., it is only necessary to move the decimal-point one place to the left in the final reading, which would give the result in the example above as 6·8μ. Similarly, if the measured unit of the stage micrometer had been 1 mm., then it would be necessary to place a cipher after the figures given in the table; so in the same example the object would have been 680 μ., or 0·68 mm. When the unit of the stage micrometer is 0·1 in., the decimal-point must be moved three places to the left; with a unit of 0·01 in., four places; and with a unit of 0·001 in. five places to the left. In the example above, the object would measure 0·068 in., 0·0068 in., 0·00068 in. respectively. The table is published by Messrs. H. F. Angus & Co., 83, Wigmore Street, London, W., price 3*d*.

The President said they were very greatly indebted to Mr. Nelson for this table, and to Mr. Grundy for putting the matter before them in the way he had done. For his own part he would welcome anything which saved him from multiplication, and he should imagine from what he had heard that this was a sort of ready reckoner for the microscope, and would be extremely useful to any one who had many measurements to make. He thought he should find a great use for it in checking his own results by comparison.

Mr. Ainslie thought that the table promised to be extremely useful to those who wished to make measurements of minute objects. If, however, instead of 28 they happened to find 28·7 or 29·3 it would merely be necessary to alter the tube length so that the stage micrometer below covered a certain value of the eyepiece micrometer.

In measuring diatoms the tube length must be adjusted, and having determined that, they must be careful not to touch the correction collar, as that would at once alter the power of the objective.

Mr. D. J. Scourfield, F.Z.S., F.R.M.S., read a paper upon a new Copepod found in water from hollows on tree-trunks. He stated that in recent years, owing to the endeavour to discover the life-histories of mosquitoes and other insects supposed to be connected with the dissemination of tropical diseases, much attention had been given to the subject, and, according to a recent paper published by Picado, no less than 250 species of animals have been found living in this peculiar environment, forty-nine being new to science. They belonged to almost all groups of invertebrates; but naturally insects and their larvae predominate. Mr. Scourfield pointed out that in tropical forests, ponds and water on the ground are rarely met with, this making it difficult to locate the breeding-places of mosquitoes, etc., until it was found that incubation took place in water contained in little cups in tree-trunks and roots. He first commenced to look for Entomostraca in these situations after reading the celebrated Fritz Müller's description of a new Ostracod representing a new genus, *Elpidium bromeliarum*, which occurred almost constantly in association with the Bromeliaceous plants in the forests of Brazil, and, strangely enough, was to be found in no other situation. His curiosity was rewarded by finding the remarkable blind Copepod, *Belisarius viguieri*, which had not previously been found in this country. He was able to report that on several occasions he had found a new Copepod in such little reservoirs of water on trees in Epping Forest, and up to the present they have been found nowhere else. The new species evidently belongs to the Harpacticid genus Moraria, described by T. and A. Scott, found in Loch Morar, Scotland. Eight species are known, three of which have been found in the British Isles. He stated that he proposed to call it *Moraria arboricola*, because of its tree-dwelling habit. It is a very small form, the female measuring only about 1/40 in. in length, of the type of Cyclops, Canthocampus and Diaptomus. The genus is peculiarly adapted to exist in but little water, and, when placed in this element, wriggles rather than swims. In Mr. Scourfield's experience, it is mostly found in the early part of the year. He commented upon their wonderful vitality. In one case, specimens left in a bottle were kept alive for four years simply by adding a little water from time to time to make up for evaporation. Mr. D. Bryce asked if it was known how they are conveyed from place to place, and

also how they were able to resist the effects of evaporation. Mr. Scourfield, in replying, instanced that the eggs of such minute creatures, and also adults, can become embedded and dry, and remain for a long period in a condition of suspended animation. Also, that one species of Cyclops and Canthocampus form a kind of cocoon. As to their distribution he could give no information.

Amongst other interesting exhibits was a specimen of *Stephanoceros Eichornii*—a wonderful example of the art of mounting, by Mr. C. F. Rousselet, Curator R.M.S.

At the 503rd Ordinary Meeting of the Club, held on December 22nd, the Vice-President, Prof. E. A. Minchin, M.A., F.R.S., in the chair, the minutes of the meeting held on November 24th were read and confirmed.

Mr. Frederick Knott was balloted for and duly elected a member of the Club.

A vote of thanks was returned to Mr. C. F. Rousselet, Curator R.M.S., for a valuable donation to the Cabinet of twenty-four slides of Rotifera.

Mr. J. Grundy read a communication from Mr. E. M. Nelson of great interest to metallurgists. A slide was exhibited consisting of a thin aluminium disc of about 1 mm. in diameter, such as Mr. Morland uses when mounting selected diatoms, mounted by itself. When placed under a $\frac{1}{4}$-in. or $\frac{1}{6}$-in. objective, and illuminated by one of the universal condensers, lamp and bull's-eye, a strong top-illumination is obtained by reflex light from the front lens. Mr. Nelson states that this idea may prove useful for the examination of metals, as, instead of using a cubic $\frac{1}{2}$ in. for examination, if the end of a wire, say, 1·5 mm. thick and 2 mm. long, was polished and fastened on a slip, the metal might be investigated probably quite as well as with a larger piece. He further stated that this idea was by no means new, as it was first expounded by Rainey sixty years ago, and later by Prof. B. T. Lowne about 1888, and again more recently by J. W. Gordon at the R.M.S.

To those interested, the valuable description by Prof. Lowne on top-lighting by reflections from the front and back of the front lens of the objective will be found on p. 371, vol. iii., second

series of the *Journ. Q. M. C.* Mr. Grundy exhibited a slide of mounted copper which illustrated the same lighting.

Mr. J. Wilson read some notes by Mr. H. Whitehead, B.Sc., F.R.M.S., on an epizoic infusorian, *Trichodina Steinii* C. and L., found on Turbellaria. These were found on a specimen of *Mesastoma tetragonum*, moving about over the surface of the body and between the folds. They are a species closely allied to *Trichodina pediculus*, which is frequently found on Hydra, but differs in that *T. pediculus* has an inner as well as an outer ring of teeth. The body of *T. Steinii* varies considerably in shape; but when at rest it is cylindrical, the diameter at the base being equal to the height (about 40 μ.), the basal circle of cilia being in contact with the body of the Turbellarian, while the adoral cilia form a spiral leading to the mouth. When free-swimming, the adoral cilia are retracted, while the basal circlet is used for the purpose of locomotion. The protoplasm contains a number of small spherular structures, and one or two contractile vacuoles are to be seen. It possesses a large horseshoe-shaped nucleus, which can only be seen in stained specimens. Mr. Whitehead pointed out an important discrepancy which appears between Saville Kent's description (probably taken from Claparède and Lachmann) and his own observations. Saville Kent stated that the posterior horny ring was continuous and denticulate only on its outer edge. A careful examination of the adherent organ shows it to consist of an outer circle of cilia, and within this a circle composed of about eighteen or twenty separate chitinous teeth, with the points directed obliquely outwards. Vejdovsky, in 1881, published a detailed account of the species, and stated that he had found *T. Steinii* on *Planaria gonocephala*. As far as can be seen, the host suffers no inconvenience from the trichodina, and there is no evidence of parasitism; consequently the non-committal term "epizoic" is more satisfactory than "parasitic" in this case.

A discussion followed, during which Mr. Rousselet said he remembered, many years ago, finding a *T. Steinii* on a rotifer.

In reply to a question by Mr. Scourfield about the formation of chitinous teeth, the chairman stated that some stalked, non-contractile forms of Vorticella fasten themselves down by means of a kind of glue exuded by the cilia, which hardens. Probably these teeth are an adaptation of similar development.

This interesting contribution was illustrated by a series of drawings on the blackboard.

Mr. J. Burton read a communication from Mr. E. M. Nelson on "Palaeozoic Fungi." His object in bringing this subject forward was to indicate to the members the extreme interest contained in the study of the flora of palaeozoic days, and in the hope that some may take up this fascinating branch of science. Many microscopists are aware of a disease called "diatom-fever"; but Mr. Nelson can state that "palaeo-botany fever" produced a much higher temperature, and he hoped it would prove very contagious amongst the members. Every one is aware that botanical fossils have been studied for many years; but it is only during the last twenty or thirty years that material suitable for microscopical examination has been available. The so-called fossils from coal-mines in museums are not really fossils, but casts, the plants having become carbonised, and their cellular structure can no longer be seen. A piece of coal under microscopic examination would reveal no structural cell-work, for that has been changed long ago. In recent years some true fossil plants have been found so perfect that sections show the delicate cell structure almost as clearly as freshly cut and stained sections of present-day specimens. As an example of the knowledge obtained by the direct application of the microscope in such cases, Mr. Nelson takes the fact that coal was formerly considered to be chiefly formed from ferns, whereas now it is known that ferns were by no means plentiful in those days, and that the bulk of coal was formed by other forms of plants. These other plants had fernlike vegetative characters, leaves, etc., but their method of reproduction differed entirely from that of ferns. He instanced how perfectly the vegetable tissues are preserved by a slide in his collection containing a section of a small seed, with the pollen grains in the pollen chamber, just previous to fertilisation, although 50,000,000 years must have elapsed since they entered. The tracheides and the bordered pits in the cells are also well preserved. He recommends those wishing to take up this subject to read Dr. D. H. Scott's charming book, *Studies in Fossil Botany* (2 vols., Black), or *Ancient Plants*, by Miss Stopes, D.Sc. (Blackie). With reference to a slide exhibited, a section of a leaf from *Lepidodendron Harcourtii*—one of the best known fossil stems, upon which was to be observed a brown

oval ball, and quite a common object in many of these sections —a power of 200 showed that it is formed in part by little rods, somewhat interlaced, not unlike the house of the caddis-worm. They are found singly, but more often in groups, especially in those parts of leaves where the cellular tissue has been disintegrated. Mr. Nelson considers that they are correlated with this disintegration, and possibly are some sort of fungus spores (gonidia). It is needless to say that no mycelium has been observed, so that it is not possible to tell whether the invasion of the fungus took place while the leaf was living on the tree or after it had fallen.

The reading of this paper caused considerable discussion.

Prof. Minchin said he remembered Prof. Oliver stating that he had found cells in coal showing a nucleus.

Mr. N. E. Brown then stated that the brown balls shown on the slide were certainly not fungus spores, but were more likely to be of animal origin. Mr. J. Wilson concurred.

Mr. R. Paulson, F.L.S., pointed out that if they were gonidia they should be on the surface of the leaf. He was interested in the subject, as he had been trying to find out how far back lichens are to be found, and had never found traces of even the lower forms as fossils.

Mr. J. Grundy referred to an address given to the Club by Prof. W. C. Williamson (Professor of Botany, Owens College, Manchester) on "The Mineralisation of the Minute Tissues of Animals and Plants" (*Journ. Q. M. C.*, Ser. 2, Vol. V. p. 186), which holds very material information for all inclined to learn more of the subject as to what a fossil is and how formed.

Amongst other exhibits, Mr. G. K. Dunstall, F.R.M.S., showed a living specimen of the rotifer *Callidina bilfingeri*, which has only been seen twice previously in England.

At the 504th Ordinary Meeting of the Club, held on January 26th, 1915, the President, Prof. Arthur Dendy, D.Sc., F.R.S., in the chair, the minutes of the meeting held on December 22nd, 1914, were read and confirmed.

Messrs. David Griffiths, J. Grant Andrews and Arthur Boltz were balloted for and duly elected members of the Club.

The list of donations to the Club was read, and the thanks of the members voted to the donors.

The Hon. Secretary said that as the next meeting would be their Annual Meeting, at which the officers and members to fill vacancies on the committee would have to be elected, nominations must be made on this occasion. The list of officers nominated by the committee was then read, and names for the committee were proposed and seconded by the members An auditor, on behalf of members, was elected.

At the request of the chairman, Vice-President Prof. E. A. Minchin, M.A., F.R.S., read a paper giving "Some Details in the Anatomy of the Rat Flea, *Ceratophyllus fasciatus*."

The paper was illustrated by lantern diagrams projected on to the screen. A number of micro-preparations made by Prof. Minchin, illustrating the various points of structure described, were exhibited under microscopes. These Prof. Minchin kindly presented to the Club.

The President said he was sure they had all been delighted with Prof. Minchin's description of the minute anatomy of the rat flea. The main object of the researches was to trace the development of the trypanosome found in the rat flea; but they had had a full account of the flea, as a type of a class of insects which exhibited a high development of organisation. He asked the members to pass a very hearty vote of thanks to Prof. Minchin for the treat he had given them, for the trouble he had taken in bringing to the meeting so many specimens, and for his kindness in presenting the very beautiful preparations to the Club's Cabinet. This was assented to by acclamation.

At the 505th Ordinary (which was also the 49th Annual) Meeting of the Club, held on February 23rd, the President, Prof. Arthur Dendy, M.A., F.R.S., in the chair, the minutes of the meeting held on January 26th were read and confirmed.

Messrs. Mark T. Denne, Charles H. A. Brooke, W. Powell Sollis and R. E. Handford were balloted for and duly elected members of the Club.

The list of donations to the Club was read, and the thanks of the members voted to the donors.

The President informed those present that news of the death of Mr. F. W. Millett, F.R.M.S., had been received. He was one of the oldest members, having joined the Club at

its foundation in July 1865. He was eighty-two at the time of his death on February 8th, and had not been able to attend the meetings for a number of years. He was an authority on the Foraminifera.

The President asked Mr. Scourfield and Mr. Hilton to act as scrutineers of the ballot for officers and council of the Club for the ensuing year. He wished to mention that any member could erase the name of any of the officers, if he thought proper, and substitute the name of any other person in the space provided on the ballot paper for that purpose. Five members of committee would have to be elected in place of four who retired by rotation and of Mr. Heron-Allen, who had resigned. Six members were nominated at the last meeting, but since then Mr. Lionel C. Bennett had withdrawn his name, so that the number remaining would fill the vacancies.

The Hon. Secretary read the committee's report, which detailed a satisfactory year's work, though the war had somewhat interfered with the personnel of the Club.

The Hon. Treasurer read the balance sheet, which disclosed a thoroughly sound financial condition.

The adoption of the report and balance sheet having been moved and seconded, was put to the meeting by the President, and unanimously carried.

The President then asked Prof. Minchin to take the chair, and proceeded to give his annual address. The title was "The Biological Conception of Individuality."

At the conclusion Prof. Minchin said they had just listened to a most interesting and instructive address—one which they would be glad to think over and to read in their *Journal*, if Prof. Dendy would kindly allow them to print it. He moved that "The hearty thanks of the meeting be given to the President for his address, and that he be asked to allow it to be printed in the *Journal*."

The motion was carried by acclamation.

Prof. Dendy, in reply, thanked those present for the attention paid to his remarks, and said he should be extremely pleased to place the address at their disposal for publication.

A vote of thanks to the scrutineers and auditors was proposed and carried.

A vote of thanks to the officers and committee was proposed

by Mr. Capell, F.R.M.S. He did not think this should be done as a mere matter of form. The members came to the meetings and found things went along smoothly, and the work was done for them efficiently and with willingness and cheerfulness, and they all gained by the efforts of those who carried it on.

The proposal was seconded by Mr. Gammon, and carried.

The Hon. Treasurer (Mr. F. J. Perks) acknowledged the vote. He said there was a considerable amount of work done by the officers apart from that which was apparent at the meetings. He thanked them for their kind expressions, and could promise they would in the future, as in the past, do their best for the prosperity of the Club.

The scrutineers having handed in their report, the following gentlemen were declared duly elected as—

President	Prof. Arthur Dendy, D.Sc., F.R.S.
Four Vice-Presidents .	C. F. Rousselet, F.R.M.S. E. J. Spitta, L.R.C.P., M.R.C.S., F.R.M.S. D. J. Scourfield, F.Z.S., F.R.M.S. Prof. E. A. Minchin, M.A., F.R.S
Hon. Treasurer . . .	Frederick J. Perks.
,, *Secretary* . . .	James Burton.
,, *Assistant Secretary*	F. E. Robotham.
,, *Foreign Secretary* .	C. F. Rousselet, F.R.M.S.
,, *Reporter*	R. T. Lewis, F.R.M.S.
,, *Librarian* . . .	S. C. Akehurst, F.R.M.S.
,, *Curator*	C. J. Sidwell, F.R.M.S.
,, *Editor*	A. W. Sheppard, F.Z.S., F.R.M.S.
Members of Committee.	J. M. Offord, F.R.M.S. Charles S. Todd. N. E. Brown, A.L.S. Ed. E. Banham. C. H. Bestow, F.R.M.S.

FORTY-NINTH ANNUAL REPORT.

Your Committee in presenting their Report for the year ending December 1914 will scarcely need to remind members that for almost half the time covered by it, namely the last five months, conditions have been of an altogether abnormal and unpropitious character. Taking this into account, it is satisfactory to find that the number of members elected has been forty-one; this is slightly above the average of the previous six years. The resignations have been twenty-five, which is more than usual, and was largely due to enlistment and other circumstances connected with the war. The deaths have been nine, again somewhat more than the average, removing some of our older and more noted members; leaving the present membership 447.

Dr. Arthur Mead Edwards of New Jersey, U.S.A., the oldest honorary member, elected in January 1868, died in September. In November we had to regret the loss of Dr. M. C. Cooke. He has been not inappropriately called the "Father of the Club"; he was not only one of its founders, but his writings and general work must have done an incalculable amount to disseminate a popular interest in, and knowledge of, microscopy. Although he was in his ninetieth year at the time of his death he had shortly before, on the celebration of our five hundredth meeting, been able to write, with his own hand, a letter expressing his pleasure at the prosperity of the Club, and his wishes for its continuance. An obituary notice appeared in the November number of the *Journal*.

Among the losses sustained owing to the war, it should be recorded that Mr. Pledge, Assistant Secretary for nine years, has been compelled to resign his office in consequence of having to place himself at the disposal of the military authorities; and we, therefore, no longer have the advantage of his very excellent reports of our meetings in the *English Mechanic* and elsewhere, for which it has been the pleasing duty of the Committee so often to express their thanks to him. The Club is to be congratulated on the fact that Mr. Robotham kindly consented to fill the vacant

position, and for some months has earned the thanks of all by his efficiency in performing the duties connected with it.

The number present at both the Ordinary and Gossip Meetings has been good, though for the latter part of the time it has been lessened somewhat by the absence of previously regular attendants owing to engagements in various capacities in the army, as well as by the general unrest brought about by the war. On the Gossip nights there has been no less enthusiasm and good work done than previously; but the Committee wish, while thanking those who have done so much to make these meetings a success, to press upon the attention of all, the desirability of their making an effort to bring a microscope and some object for exhibition, and thus add their endeavours for the well-being of the whole.

The papers and notes read were as follows:

Communications during 1914.

January 27*th.*—Some Observations on Sub-stage Illumination, by S. C. Akehurst.

January 27*th.*—On an Attempt to Resolve *Pinnularia nobilis*, by T. A. O'Donohoe.

February 24*th.*—President's Address: Organisms and Origins, by Prof. Arthur Dendy, D.Sc., F.R.S.

March 24*th.*—Some Notes on the Structure of Diatoms, by N. E. Brown, A.L.S.

March 24*th.*—On a New Oil-Immersion Objective and On a New Method of Illumination, by E. M. Nelson, F.R.M.S.

April 28*th.*—On a New Low-power Condenser, by E. M. Nelson, F.R.M.S.

April 28*th.*—On the Fertilisation of *Vinca minor*, by N. E. Brown, A.L.S.

May 26*th.*—Notes on the Cultivation of *Badhamia utricularis*, by A. E. Hilton.

May 26*th.*—On Binocular Microscopes, by E. M. Nelson, F.R.M.S.

June 23*rd.*—Notes on Fossils from the Coal Measures, by W. E. Watson Baker.

June 23*rd.*—Notes on the History of the Club, in Celebration of the 500th Ordinary Meeting, by Dr. E. J. Spitta.

October 27*th.*—Report of the Havre Meeting of the British Association, by C. F. Rousselet, F.R.M.S., the Club's delegate.

October 27th.—On the Minimum Visible, by A. A. C. Eliot Merlin.

October 27th.—Remarks on two Species of African Volvox, by C. F. Rousselet, F.R.M.S.

November 24th.—A New Copepod found in Water in the Hollows on Tree Trunks in Epping Forest, by D. J. Scourfield, F.Z.S.

December 22nd.—On an Epizoic Infusorian—Trichodina, found on the Planarian *Mesostoma tetragonum*, by Mr. Whitehead, B.Sc.

December 22nd.—Palaeozoic Fungi, by E. M. Nelson, F.R.M.S.

Your Committee thanks the authors of these valuable communications on behalf of the members. It may be observed that short notes are more frequent than usual, and it is desired to express the appreciation in which this class of communication is held; those who are not able to undertake a lengthy and scientific paper may still be able to add their quota to the work of the Club by giving short accounts of their finds, and of the methods and experiences of their investigations.

Several new and useful pieces of apparatus—often the invention of our own members—have been exhibited and described. Notice of these will be found in the reports of the meetings in the *Journal*.

The veteran microscopist, Mr. E. M. Nelson, as in former years, has laid the Club under an obligation by his numerous and interesting communications. In May he gave a paper on "Binocular Microscopes," very fully treating the subject of the new high-power binoculars. At the same meeting Messrs. Beck and Messrs. Leitz exhibited samples of this class of instrument, thus giving an opportunity of judging their capabilities, and greatly adding to the interest of the proceedings. In November Mr. Scourfield read a paper describing a new species of Copepod he had found in Epping Forest. The discovery by Mr. Rousselet of the sexual forms of two species of African volvox, among specimens he had received from Dr. Jakubski of Lemberg, is noteworthy. The account of the experiences of Mr. Rousselet as delegate to the Havre meeting of the Corresponding Societies of the British Association on the eve of the outbreak of war is given in the *Journal*.

In February a Conversazione was held at King's College: this was much appreciated by members and their friends. It was the

first that the Club had held for seventeen years, and the hope was freely expressed that so long a time would not be allowed to elapse before another occurred.

The meeting on June 23rd was the five hundredth Ordinary Meeting. In the absence of the President—who had just left for Australia as the President of the Zoological section of the British Association—the chair was taken by Dr. Spitta, who, in celebration of the occasion, gave the meeting a more social character than usual, quite in accordance with the older traditions of the Club.

The Librarian reports that, notwithstanding some inconvenience being felt owing to the restricted space at his disposal, the average number of books borrowed in previous years has been maintained. The Library sub-committee has met regularly on the first and third Tuesdays in the month, and members will be glad to hear that, after considerable but unavoidable delay, the Catalogue of Books is in the hands of the printers. This, combined with the appointment of Mr. Todd as Assistant Librarian, will render the work of the department more expeditious, and it is hoped that advantage will be taken of the increased facilities. The best thanks of the Club are due to Mr. Todd, to Mr. Sheppard and to Mr. Bennett, for the interest and energy they have exercised in carrying out the by no means light task of reorganising the Library.

List of Books Purchased and Presented since October 29th, 1914, to January 1915.

Memoirs of Indian Museum. Vol. III. 4. Oriental Passalidae (Coleoptera). F. H. Graveley, M.Sc.

Presented by W. Harold S. Cheavin.

Water Beetle (*Dytiscus marginalis*), Common Gnat (*Culex pipiens*).

Reports on Hydroida collected in the Great Australian Bight and other Localities. Parts II. and III. W. M. Bale, F.R.M.S.

Purchased.

Some Minute Animal Parasites. Fantham and Porter.

Missouri Botanic Garden.
Philippine Journal of Science.
Bergen Museum.
United States National Herbarium.
Royal Society. B Series.
Natural History Society of Glasgow.
Zoologisch-botanischen Gesellschaft Wien. LXIV. Parts 1–4. 1914.
United States National Museum.
Nuova Notarisia.
Liverpool Microscopical Society.
Royal Dublin Society.
University of California.
Illinois State Laboratory of Natural History.
Société Royale de Botanique de Belgique. Tome LII. Series II. March 1914.
Brighton and Hove Natural History and Philosophical Society.
Edinburgh Royal Botanic Garden
Northumberland and Durham Natural History Society.
Torquay Natural History Society.
Photographic Journal.

During the year ending December 1914 the Library has received the following publications:

Quarterly Journal of Microscopical Science.
Victorian Naturalist.
Mikrokosmos. Up to Part 5. 1914–1915.
Royal Microscopical Society.
British Association Report.
Royal Institution of Great Britain, Proceedings of.
Geologists' Association.
Manchester Literary and Philosophical Society.
Hertfordshire Natural History Society.
Botanical Society of Edinburgh.
Tijdschrift.
Nyt Magazine.
Manchester Microscopical Society.
Birmingham and Midland Institute.
Glasgow Naturalists' Society.

Croydon Natural History Society.
Indian Museum, Calcutta.
Royal Society of N.S.W.
American Microscopical Society.
Smithsonian Institution.
Academy of Natural Science, Philadelphia.
Missouri Botanic Garden.
Philippine Journal of Science.
Bergen Museum.

During the year eleven excursions were held, at which the average attendance was 23, against 20·8 for last year. Notwithstanding the inclement weather on some of the dates, the average attendance for the year is a record. An excursion had been arranged for August 8 to Hampton Court, but owing to the unfavourable weather and the excitement caused by the war, it was abandoned. Arrangements had also been made for an excursion to the East London Water Works, but owing to the war, the authorities cancelled the permission. An excursion instead was made to various ponds in Epping Forest, which was very successful. There were no new species to record, but *Lemna minor* was found abundantly in flower in one of the ponds in Trent Park. The thanks of the Committee are due to His Grace the Duke of Northumberland and to Sir Philip Sassoon for the permission to visit their private grounds.

The Curator reports that all through the year there has been a steady demand for the slides and instruments under his care, and 111 preparations have been added to the Cabinets. The principal addition has been the purchase of 47 fine slides of selected Diatoms mounted in styrax, thus bringing up the Club's collections of Diatomaceae to 1,550 preparations. For some time past Mr. Rousselet has been engaged in the onerous task of overhauling, and in many cases remounting, the type-collection of Rotifera he presented to the Club some years since, to which he has recently made a further donation of 24 slides, thus increasing the total to over 260 species. The cordial thanks of the Club are due to Mr. Rousselet for his labours, and the Club is to be congratulated on possessing what is believed to be the most complete type-collection of Rotifera in the world, with the exception of Mr. Rousselet's private collection. Up to

the present these slides have only been available for reference at the rooms; but after careful consideration the Committee has decided to lend out the preparations, under certain conditions, to members specially interested in the group. The Committee has felt it necessary to make some restriction, owing to the delicate nature of the slides, and the difficulty of replacing many of the rarer species in the event of accidental damage, as any such loss would considerably detract from the value of the preparations as a type-collection. The demand for slides is generally from the newer members, and the Committee regrets that greater use is not made of the Cabinets by the older members and those who are specialising, as the Cabinets contain many preparations which could not fail to be of use and interest to them. The Curator will be pleased to render any assistance and information in this respect.

The Committee again begs to tender its best thanks to Mr. Bestow for kind assistance rendered to the Curator in the issue of slides.

Thanks are due to the Editors of the *English Mechanic* and of *Knowledge* for their kindness in publishing reports of the Meetings.

Your Committee desires to thank the various Officers for the unabated energy they have displayed in carrying on the work of the Club, work which they are conscious not seldom entails a considerable amount of self-denial, but the reward for which is the continued prosperity and usefulness of the Club, founded now nearly half a century ago.

THE TREASURER IN ACCOUNT WITH THE QUEKETT MICROSCOPICAL CLUB

Dr *For the year ending December 31st, 1914.* Cr.

	£	s.	d.		£	s.	d.
To Balance from 1913	208	7	10	By Rent	75	0	0
„ Subscriptions	222	10	0	„ Expenses of *Journal*	130	16	9
„ Dividends on Investments	14	5	4	„ Postages, etc.	6	0	0
„ Sales of *Journal*	15	12	1	„ Printing and Stationery	12	0	10
„ Sales of Catalogues	1	7	6	„ Attendant	4	1	3
„ Advertisements	28	12	9	„ Petty Expenses	2	3	7
„ Conversazione	9	0	0	„ Books, etc.	14	18	7
„ Legacy, J. M. Allen, deceased	53	19	7	„ *English Mechanic*	8	16	10
				„ Conversazione	28	1	9
				„ Purchase of Consols	100	0	0
				„ Balance in hand	171	15	6
	£553	15	1		£553	15	1

INVESTMENTS.

	£	s.	d.
2½ per cent. Consols	334	1	6
Metropolitan Water Board Stock	100	0	0
Metropolitan Consolidated Stock	100	0	0
2½ per cent. Annuities, 1905	100	0	0

We have examined the above Statement of Income and Expenditure and compared the same with the Vouchers in the possession of the Treasurer, and have verified the Investments at the Bank of England, and find the same correct.

February 9th, 1915.

J. WILSON
ALFRED E. HILTON } *Auditors.*

F. J. PERKS, *Treasurer.*

OBITUARY NOTICE.

FORTESCUE WILLIAM MILLETT, F.G.S., F.R.M.S.

Born November 8th, 1833; *died February 8th*, 1915.

It is with feelings of great regret we have to record the death, in his eighty-second year, of Mr. F. W. Millett, which took place on February 8th at his residence in Brixham, Devon.

Mr. Millett was a native of Marazion, in Cornwall, and when about twenty years of age came to reside in London. From an early age he was of a studious nature, and his connection with the Quekett Microscopical Club—he joined at its foundation in July 1865—fostered an early taste for microscopical work. He was elected F.R.M.S. in 1880, and in 1883 left London to reside in Cornwall. From about that date the study of the Foraminifera became his principal life-work.

His first paper, "The Foraminifera of Galway," written in collaboration with F. P. Balkwill, was published in the *Journal of Microscopy and Natural Science* in 1884. It was a paper of considerable zoological importance, but the lithographed plates were very poor, and it is not surprising that Millett later revised the paper and issued it in 1908 as a private reprint with half-tone reproductions of the original excellent drawings. Between 1885 and 1902 Millett published a series of short papers on the Foraminifera of the Pliocene Beds of St. Erth, Cornwall, which obtained for their author recognition from the Royal Geological Society of Cornwall in the form of the William Bolitho gold medal. But his future reputation will rest principally and securely on his "Report on the Recent Foraminifera of the Malay Archipelago," which appeared in the *Journal of the Royal Microscopical Society* at intervals between 1898–1904. This monograph, illustrated profusely by the author, dealt with a new zoological area and contained descriptions of many new and interesting forms. But its chief value to the student lies in the careful research work embodied in the author's bibliographical references to the numerous species which he recorded from the material examined. This was unquestionably Millett's strongest

point, for he had devoted a lifetime to the collation and assimilation of the work of his predecessors, both British and foreign, and no man had a wider knowledge of the subject, or was more ready to place it at the disposal of fellow-workers.

With the death of F. W. Millett passes almost the last survivor of the famous band of systematists who have made British research into the Foraminifera famous throughout the world. Started by Williamson and continued by the famous collaborators W. K. Parker, Rupert Jones and H. B. Brady, and by the equally distinguished W. B. Carpenter, their systematic work has reduced to a more or less exact if artificial science the chaos in which the group had previously existed. Millett assisted Brady in the preparation of the great "Challenger" report (1884), to what extent it is impossible to say, but probably he was largely responsible for the elaborate synonymies which render that report so valuable. He also collaborated in the *Monograph of the Foraminifera of the Crag*, published by the Palaeontographical Society, and here his systematic work is more easily traced. If his total output of publications is small as compared with other workers in the group, it was largely due to the painstaking care which he lavished on his work. Few rhizopodists will be less revised by the publications of their successors than F. W. Millett, and after all that is the real test of scientific work.

AN ADDITION TO THE OBJECTIVE.

By M. A. Ainslie, R.N., B.A., F.R.A.S.

(*Read April 27th*, 1915.)

Figs. 1 and 2.

Probably there are few microscopists who are in the habit of using high-power dry objectives who would not agree that the correct adjustment of the tube-length to suit the thickness of the cover-glass is with such lenses of great importance if good definition is to be obtained. Definition of a sort may, it is true, be got with incorrect tube-length; but only by unduly closing down the iris diaphragm and thus reducing the illuminating cone, or otherwise interfering with the uniformly illuminated back lens which is the basis and starting-point of all correct microscopic vision. In the present paper I am not considering inferior definition got in this way; I am only considering the question of obtaining really sharp definition, with a cone of illumination which utilises at least two-thirds of the aperture of the objective; and this is what I mean when I speak of "good" definition; and such is only to be obtained by careful adjustment of the tube-length to suit the thickness of the cover-glass.

With objectives fitted with correction collars this paper has not much to do; the correction collar to a large extent obviates the change of tube-length without interfering much with the magnifying power, and is useful in other ways, as for example in focusing through the various planes of a thick object; but unfortunately it seems to be going out of use, except in the dry apochromats and in water-immersions; and as 99 out of 100 of the high-power dry objectives met with at the present time are without this appliance, I shall not take it into further consideration, but confine my attention to the objective as commonly used.

If we open a treatise on Microscopy, we are pretty sure to find the question of cover-glass and tube-length alluded to more or less (usually less) fully. The reader is told that for a thick

cover-glass the tube is to be shortened, and that it is to be lengthened for a thin; and the importance of the matter is impressed on the reader, even to the extent of saying that "the correction of the objective and the tube-length ought to vary with every object" (Dallinger), a statement which would appear to require some modification in the case of oil-immersion objectives.

Little, however, is usually said as to how the correct tube-length is to be recognised when obtained, and nothing as to how much we may expect to have to move the draw-tube. On this latter point I hope to give some data which may prove useful.

One of the first things to strike any one who tries to examine a few mounted specimens, with, say an 1/8th, is that the range of draw-tube of the modern stand is often insufficient to allow for more than a very slight variation in the thickness of the cover-glass; and this is more particularly the case with stands of Continental make, in which the available range is often not more than 50 mm.; and to give some idea of what a hindrance to observation this may prove, I may say that with an English stand (by Watson) having the good range of tube-length of 92 mm., and using a Leitz No. 7 (which is a 1/8th of N.A. 0·85), I have found it impossible to examine some of the beautiful slides of Diatomaceae in the Club Cabinet, in some cases because the cover-glasses were too thin, and in other cases because they were too thick. With the limited range of the Continental draw-tube one would, of course, be still worse off.

Another point on which the text-books are silent, but which soon becomes evident to any one who has occasion to use objectives of different powers, is that the change of tube-length necessary to correct for a given variation in the thickness of the cover-glass is not always the same; it varies enormously with the power of the objective, and also, to some extent, with the formula on which the objective is constructed. At one end of the scale we have such objectives as the half-inch "Holos" of Watson & Son, N.A. 0·65, which requires a change in the tube-length of about 1·2 mm. only to compensate for a variation of 0·01 mm. in the thickness of the cover-glass; and the Zeiss 12 mm. Apochromat, of the same N.A., which requires a change of about 2 mm. under the same conditions.

These objectives have, in fact, the extremely useful property of working through almost any cover-glass; even through a thin slip, if the tube-length be closed down sufficiently, which in the case of these objectives is almost always possible.

As we increase the power of our objectives, the alteration required in the tube-length increases rapidly; to give only a few instances, the figures are roughly as follow for certain typical objectives:

Watson 6 mm. Holos, N.A. 0·84 . . .	3·4
Leitz No. 5 (1/5th-in.)	7·5
Watson 1/6th-in., N.A. 0·74	9·0
Zeiss " G " water-immersion	9·5
Zeiss 4-mm. Apo. (without using correction collar)	13·0
Leitz No. 6 (1/6th-in.)	14·0
Leitz No. 7 (1/8th-in.)	20·0

So that a typical 1/8th-in. is ten times as sensitive in this respect as the Zeiss 12-mm., and seventeen times as sensitive as the Watson 1/2-in. " Holos."

In passing, I must say that this seems to me to be a strong point in favour of the employment of objectives of moderate power, as long as they are of sufficient excellence to stand the high eye-piecing necessary to give the desired magnification. The difficulty of using such a lens as the Leitz No. 7 with a range of only 50 mm. in the draw-tube will now be fairly obvious.

It might be thought that a good deal of this difference between objectives of different powers is due to the N.A. of the higher powers being, as a rule, greater than that of the lower; but the above figures are practically unaltered when the N.A. is reduced to about 0·6 in each case, though of course the effect of incorrect tube-length on the definition is not so marked as with the full aperture.

Although I am confining my attention to objectives with N.A. not less than about 0·65, it must not be thought that those of lower N.A. are altogether insensitive to correct tube-length; a 25-mm. objective of N.A. 0·3, for example, will not work really well at any but its computed tube-length, although such objectives are not very sensitive to alterations in the thickness of the cover-glass.

I now come to the device which I am bringing to your notice for overcoming the difficulty caused by insufficient range of draw-tube.

Many years ago the late Dr. Van Heurck used what he called a "transformer," for the purpose of enabling short-tube objectives to work on the long tube, and *vice versa*. I do not know that he used it for any other purpose, or with a view of compensating for insufficient range in the draw-tube.

He applied, behind the objective, a lens of small power, either convex or concave, according to the effect desired, and stated that in this way he was able to use even a 2-mm. Apochromat, corrected for the short tube, on the long tube, without any appreciable loss of definition. The lenses he used were, I believe, achromatic.

But it has occurred to me that the utility of this device is of far wider range than this. In the course of a series of experiments with a large number of dry objectives of various (high) powers, I have found that it is possible to increase very greatly the range of thickness of cover-glass through which the objective will give good definition; and I hope, later on, to show another use for this additional lens, which has not, so far as I am aware, been described before.

If a convex or concave lens of low power be introduced immediately behind the objective, it has the effect of altering the degree of convergence of the rays of light projected by the back lens of the objective, and thus of altering the position in which the image is formed. Conversely, if the objective requires, to give good definition, that the image should be formed in a plane either within, or beyond, the available limits of the tube, it is perfectly possible, in the great majority of cases, to find a lens of such a power that its introduction above the objective will bring the image within the limits of the tube.

Suppose, for example, that we have a cover-glass so thick that the objective will only form a perfect image of the object at a point too close to the back lens for the tube to be sufficiently shortened; it is true that we can, by using the focusing adjustments, bring the image to the top of the tube, but then we do not get a perfect image; that is to say, not perfect in the sense

that it is the best that the objective will do. A perfect image is only formed, for any given thickness of the cover-glass, at one particular distance from the back lens, and at no other.

To take a numerical example, which will probably help to make this point clearer, suppose we have a cover-glass so thick that the correct tube-length is no more than 100 mm. It is obvious that the tube cannot be closed down as much as this, except on a stand of very exceptional construction.

To treat the objective for the moment as an animate thing, we can as it were leave it under the impression that it is forming the image at the point where it can do so best, *i.e.* at 100 mm. from the bottom of the tube. If we now introduce behind the back lens a concave lens of low power, we decrease the convergence of the beam projected by the objective. This in no way affects the working of the objective, since the action of this new lens does not commence until the objective has finished its work; but if the power of the additional lens is suitably chosen, we can so alter the degree of convergence of the beam of light as to make it come to a focus, say, at a distance of 170 mm. from the back lens—that is to say, well within the limits of an ordinary draw-tube. We have, in fact, altered the tube-length for which the objective is corrected. If the thickness of the cover-glass be still further increased, we have only to introduce a lens of shorter focus, and therefore of greater power, to bring the image within the limits of the draw-tube as before; and it will readily be seen that this gives us the power, within somewhat wide limits, of obtaining good definition through a thickness of cover-glass which would in ordinary conditions be a complete bar to anything like good definition.

Conversely, if the cover-glass is inordinately thin, the distance at which the perfect image will be formed may be considerably beyond any length that the draw-tube will reach; but the introduction of a convex lens of suitable power will increase the convergence of the beam of light, and so bring the image to a distance at which the draw-tube can deal with it.

Figs. I. and II. are intended to illustrate the action of the additional lens; in each figure,

P is the object;

O is the objective, shown diagrammatically as a single lens

C is the cover-glass (thick in I., thin in II.);

A is the additional lens (concave in I. for a thick cover, convex in II. for a thin) ;

U and L are the upper and lower limits, respectively, of the draw-tube ; the image must be formed between these limits to be capable of being focused by the eyepiece ;

V is the point at which the objective must produce the image, if it is to be the best possible ; it will be seen that in each case V lies outside the limits of the draw-tube, so that the best possible image could not be focused by the eyepiece ;

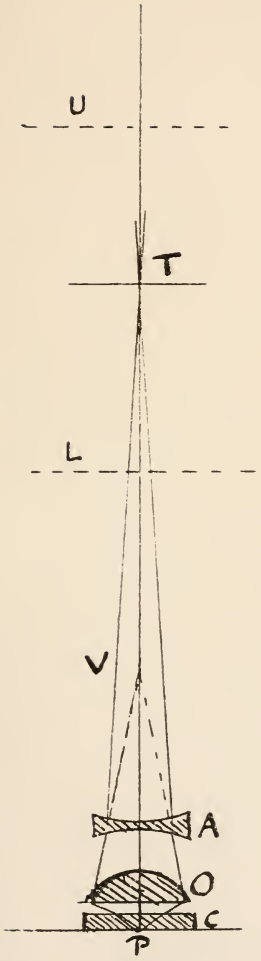
T is the point, well within the limits of the draw-tube, to which the image V is transferred by the additional lens.

The actual path of the rays is in each figure shown by dark lines ; the broken lines show the paths that would be followed in the absence of the additional lens.

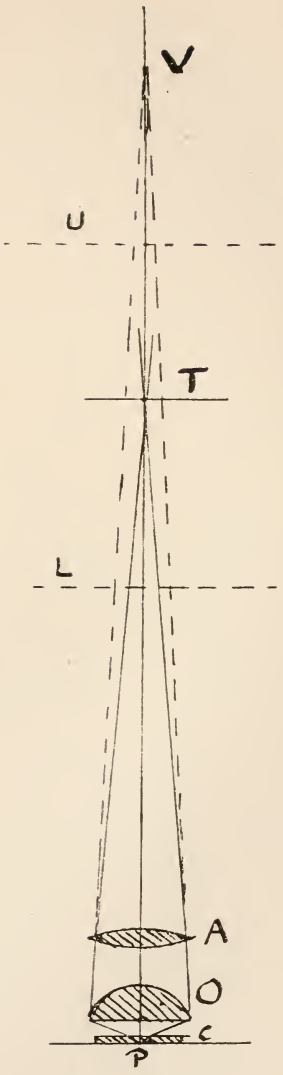
It would, no doubt, be possible, by the use of the focusing adjustments of the microscope, to bring an image of a sort, in either case, within the limits U, L ; but it would not be the best possible, indeed in the majority of cases it would be very inferior, owing to the tube-length being incorrect ; the function of the additional lens is to allow the objective to work at the proper tube-length OV, but to bring the " best possible " image, formed at the proper tube-length, within the available limits of the draw-tube.

With objectives of not too high power—the ordinary 1/6th-in., for example—there is scarcely any limit to the amount of correction which can be produced in this way. Take, for instance, an objective (Watson 4 mm. Apochromat, N.A. 0·85) corrected in the usual way to work through a cover-glass 0·18 mm. in thickness, working on an uncovered object, and it will be seen that the definition is good. In this case a convex lens of + 4 diopters is placed behind the objective. With a dry 1/8th-in., however, or with dry objectives of still higher power, it is not possible to go quite so far as this, though the results to be obtained are by no means bad.

I am showing the objective working on an uncovered object with a view of demonstrating the amount of correction that may be obtained in this way ; at the same time I ought to say that this is not the best way of making an ordinary objective work on an uncovered object : the best and easiest method is by



I.



II.

oiling to the front lens a small piece of cover-glass of the thickness for which the objective is corrected, which will enable it to work exactly as it was intended to work. As far as the aberrations produced are concerned, it is a matter of indifference whether we place the cover-glass next to the object or next to the front lens; and the advantage of oiling it to the front lens is that there are no reflections introduced to dull the image.

If the precise change in tube-length necessary for a given change in the thickness of the cover-glass were known in the case of a given objective, there would be no difficulty in calculating the power of the additional lens required to effect the correction; but, as has been seen, objectives vary so enormously in this respect that it is of little use to give any rules for the purpose. Each objective ought to be fitted with appropriate lenses, just as a defective eye has to be fitted with spectacles Speaking generally, it will be found that with the ordinary 1/6th-in., a pair of lenses, convex and concave, if about 10-in. focus, or + and − 4 diopters, will cover all the ground likely to be required. With lenses of this power, and a range of tube-length from 167 to 259 mm., I find that a Watson 1/6th-in., of N.A. 0·74, corrected normally for a tube-length of 200 mm., and a cover-glass 0·18 mm. thick, will give good definition with any thickness of cover-glass from zero to 0·35 mm.; with a concave lens of 10 diopters, or 4-in. focus, the thickness can be as much as $\frac{1}{2}$ mm. Without the additional lens, the variations of thickness of cover-glass which can be allowed for with the above range of draw-tube is from 0·11 to 0·21 mm., so that the introduction of the lenses of + and − 4 diopters has more than trebled the range of thicknesses through which the objective will work. This particular objective is rather a favourable example, since its sensitiveness to cover-glass thickness is less than that of many objectives of its power; but with any objective of this power, and to a somewhat less extent with objectives of higher power, the advantage of this device is evident. With objectives of higher powers, the available range of thicknesses is less, unless the power of the additional lens is raised; for example, a Leitz No. 7 cannot be made to work on uncovered objects in this way unless with a convex lens of at least 10 diopters power, or 4-in. focus, and even then the result is not nearly so good as in the case of a 1/6th-in. This again illustrates the

advantages possessed by objectives of medium power over those of very high power.

It will be seen then, I think, that this device places a considerable power of correcting for cover-glasses of abnormal thickness in the hands of the microscopist, especially with the miserable 50 mm. range of the Continental draw-tube; and it now remains to be seen what the effect of this additional lens is on the power, N.A., and corrections, spherical and chromatic, of the objective.

Firstly, as regards the power. If the additional lens could in practice be fitted in the "upper focal plane" of the objective—that is to say, in the plane in which a pencil of parallel rays entering it from below would come to a focus—there would be no alteration of power. But in most objectives—in all those of high power, in fact—this upper focal plane is not far behind the front lens, and therefore inaccessible. So we have to put up with a certain increase of power in the case of the concave lens, and a decrease in the case of the convex; but if the power of the additional lens does not exceed 4 diopters either way, *i.e.* if its focal length is not less than 10 in., the alteration of power is not serious. It is an advantage to have the additional lens as near as possible to the back lens of the objective, but if there is any difficulty in fitting it there, it does very well to place it on the nosepiece.

The effect on the working distance of the objective is not serious: the concave lens increases the working distance, and the convex lens diminishes it; but since the former is used in the case of thick cover-glasses, and the latter in the case of thin, it will be seen that the change is in the right direction, so that this point need not worry us.

Similarly the effect on the N.A. is not great. The convex lens somewhat diminishes it, and the concave lens may (it does not always) slightly increase it; but the change is not great, and for most purposes unimportant.

It is of more importance to inquire what effect, if any, the introduction of the additional lens has on the spherical and chromatic corrections. To take the former, it so happens that the spherical aberration introduced by the additional lens slightly counteracts its effect in producing the result desired; a simple uncorrected lens does not quite produce the full theoretical effect

it would have if it were corrected for spherical aberration; but in any case the additional lens is small, and of low power, so that the effect of its spherical aberration is very slight, and only involves a small movement of the draw-tube. Since the final adjustment of the draw-tube would in any case be performed by actual inspection of the image, it will be easily realised that the effect of the spherical aberration of the additional lens is quite unimportant.

With regard to the chromatic effect, I have only used simple uncorrected lenses in my experiments. Even with these, the effect on the colour correction of the objective is extremely small, except perhaps in the case of an additional lens of 10 diopters.

The only effect that is at all noticeable is that with the convex lens in use the "compensation" required in the eyepiece, to do away with the chromatic difference of magnification (present in all lenses having a single front lens) is somewhat diminished; in the case of the concave lens, it is somewhat increased; but this effect is only seen if specially looked for, and with ordinary Huyghenian eyepieces would not be noticed.

There is, however, a curious effect to be seen in some cases, with objectives which under normal conditions show a certain blue tint on the margins of black objects; and many of the finest achromatic lenses of the present day, noticeably Watson's Holoscopic, show this effect, which indeed I am informed betokens a more than usually good spherical correction, and in consequence more than usually good definition. I have a Holos 25 mm. objective, of measured N.A. 0·31, corrected for the 250 mm. tube; this, on black objects, such as the lines on the Abbe test plate, shows the blue tint I have alluded to. When the correction of this lens is altered to the short tube by the introduction of a convex lens of 2 diopters (20 in. focus), the blue tint almost disappears, and the total quantity of outstanding colour is greatly diminished, so that the additional lens has a sort of "apochromatising" effect; this is probably due to the fact that the additional lens slightly alters the "preferred colour," for which the spherical correction of the objective is carried out; but to my eyes there is little, if any, loss of definition on this account, and the 27 compensating eyepiece can still be used with advantage.

The additional lenses above described are easily fitted behind the objective if they are mounted in small cells which push into a ring made to screw to the nosepiece, and having a thread in front to take the objective. Otherwise they may, as stated above, be fitted immediately behind the back lens, and almost in contact with it; but this is hardly necessary, unless it is important that the power of the objective should be affected as little as possible. The lenses I have had made are just over 14 mm. in diameter, and the outside diameter of their cells is rather less than 15·5 mm., so that there is ample room for them to push into the upper side of the ring suggested, leaving sufficient thickness in the ring for the thread to fit the nosepiece.

They were beautifully made and fitted for me by Messrs. H. F. Angus & Co., who supplied me with a series of 11 of these lenses, varying in power from + 10 to − 10 diopters. With this series almost anything can be done in the way of cover-glass correction.

I have tried both biconvex and biconcave, and plano-convex and plano-concave lenses, the latter with the plane side both upwards and downwards, without being able to see any difference in the performance; biconvex and biconcave lenses are easier to obtain, and I should recommend them to any one thinking of trying this device.

So far we have been dealing with the use of an additional lens with dry objectives; but I now come to a use for this device which has not, as far as I know, been suggested before. I refer to the conversion of an oil-immersion objective into a water-immersion.

Some time ago I found that with certain oil-immersion objectives it was possible to get good definition with glycerine as the immersion fluid if the tube length was increased by 60 mm. or so. Was it possible to use these objectives as water-immersions?

The substitution, in the case of an oil-immersion objective, of a medium of smaller refractive index for the oil has an effect on the corrections of the objective precisely similar in kind to the reduction in the thickness of the cover-glass in the case of a dry objective; in each case the effect is really due to the

reduction of the average refractive index in the space between the front lens and the object, except that in the case of the substitution of water for oil the effect is greatly increased.

It was quite obvious, the moment I tried the experiment, that mere increase of tube-length would not by itself make an oil-immersion 1/12th work as a water-immersion, on any cover-glass that was likely to be met with; but as soon as the idea of the additional lens, as described above, occurred to me, it immediately suggested itself as a way out of the difficulty. But, as a rule, in the case of the conversion of an oil-immersion into a water-immersion, the power of the additional lens has to be much greater than is required with a dry lens, to correct for an unusually thin cover-glass. In fact, it is generally necessary to use a lens of such great power that the pencil of rays emerging from the back lens of the objective is actually divergent instead of convergent; so that the correct position for the image has actually "passed infinity" and the tube-length is negative, or, in other words, the best image that can be formed by the objective is a "virtual image" several inches below the object! It is hardly necessary to say that this means upsetting all the corrections of the objective, and at first sight it does not look very promising.

But on trial it was found that it was only the extreme margin of the objective that was adversely affected. With an illuminating cone of not more than about 0·75 or 0·8 N.A., the definition becomes quite satisfactory, and it appears that the central portion of the objective is not to any great extent affected by the violence done to it.

Here again, as with dry objectives, an objective of moderate power is much more amenable to the action of the additional lens than one of very high power. The Zeiss 1/7th-in., of N.A. about 0·93, only requires a convex lens of 2 diopters, or 20 in. focus, to effect the conversion; a Leitz 1/10th-in., the focus of which is about 2·75 mm. (so that it is really a 1/9th-in.), requires 8 diopters, or 5 in. focus; and a Watson "Parachromatic" 1/12th-in. (actually a 1/14th-in. of N.A. 1·30) requires a lens of 10 diopters, or 4 in. focus. I have not experimented with any stronger lenses, nor do I think that this arrangement would be of much use with such.

Even if we have to sacrifice a little of the aperture of the lens, however, it seems to me that there is a distinct field of utility for this method of conversion. The effect on the definition, at any rate in the centre of the field, of the additional lens is extremely small; and with a 1/12th-in. oil-immersion, treated in this way, I have been able to get clear and strong resolution of *Amphipleura Lindheimeri* in styrax, which, though not an exhaustive test for a water-immersion, yet requires a pretty good lens to give a really good image.

The useful limit of N.A. for a lens treated in this way is, I think, about 1·15. It is not very likely that the full aperture of the objective would be available, when one considers that the full N.A. of an oil-immersion treated in this way is something like 1·29 out of a possible 1·33, and that no water-immersion has so far been put on the market, even apochromatic, with a greater N.A. than 1·25. If we are content, however, to sacrifice a little of the margin of the lens, we can get a good water-immersion of about the aperture named, which should be useful for occasional use at any rate, when it is not worth while going to the expense of a proper water-immersion objective.

It is a somewhat unfortunate, though unavoidable, circumstance that the introduction of the additional lens shortens the working distance, considering the limited working distance already possessed by the average oil-immersion; at the same time, the 1/12th-in. alluded to above will work through a cover-glass as much as 0·20 mm. thick, and it is easy to obtain cover-glasses thinner than this; and it appears to me that it is only on temporarily mounted specimens, such as films of living bacteria, and the like, that one would want to use a water-immersion, the great superiority of an oil-immersion on any permanently mounted object being undeniable.

For biological, medical, and other work that requires the examination of living objects, I think there is a real sphere of usefulness for this method of conversion. But at the same time, it should be noticed that the advantages of the method are more pronounced if the oil-immersion objectives employed are of medium power, and a 1/10th-in. is certainly more suited to the additional lens than a 1/12th-in.

The conversion of an oil- into a water-immersion is particularly useful when it is desired to examine living bacteria on a dark

ground. It sometimes happens, when an oil-immersion is used for this purpose, that the cover-glass has an unpleasant knack of sticking to the front lens of the objective; with a water-immersion this difficulty is absent. Also, there is the distinct advantage that it is easy to remove the water if it is desired to examine the object with a dry lens, whereas this is by no means an easy matter in the case of oil. The performance of the Zeiss 1/7th-in., used as a water-immersion, upon living objects on a dark ground is especially good, though the Leitz 1/10th-in. is not far behind.

In the case of an oil-immersion, it is well to have the additional lens fitted as close to the back lens of the objective as possible; there is no difficulty in doing this, as it is usually the practice of makers to supply a "funnel stop" to which the optical part of the objective can be screwed. If the stop is removed, and the additional lens fitted in its place, so as to be close to the back lens when the optical part is screwed on, the effect on the magnifying power is not serious, and can be disregarded. In the case of the Leitz 1/10th-in., for example, the objective in its normal state has a focal length of 2·75 mm., and is a 1/9th-in.; with a lens of + 8 diopters in position immediately behind the back lens, the focal length is 3 mm., and the objective becomes a 1/8th-in.

For dark-ground work, of course, the aperture must be reduced to something like 0·85, with the dark-ground illuminators of the present day; and we may either fit a separate "funnel stop" with a small lens in it, giving this aperture, or use the funnel stop as it stands, and fit the lens in rear of the objective mount. This, of course, reduces the power rather more than the other arrangement, but this is not serious, as sufficient power can be obtained by the use of a deeper eyepiece.

It should be noted that when the oil-immersion has been converted in this way to a water-immersion, it becomes sensitive to variations in the thickness of the cover-glass, though not to the same extent as a dry objective; the draw-tube will as a rule be able to deal with this, but if more correction is required it can be obtained by means of additional lenses, in the manner described above for dry objectives.

I have left to the last, principally because it is more interesting than practically useful, what is, from the "brass and

glass " point of view, perhaps the most remarkable use to which the additional lens can be put.

This is the conversion of a dry objective into an oil-immersion. In the great majority of cases this cannot be done, not only because it is too radical a change for most objectives, but because the working distance is as a rule too great to admit of oil-contact.

But there are certain objectives of comparatively low power, and small working distance, with which it is possible. The matter only occurred to me a day or two ago, so that I have not had the opportunity of trying the experiment with more than two lenses ; with one of these, however, a 6-mm. Holos of the earlier construction, having an N.A. of 0·84, I succeeded fairly well.

The additional lens required is a concave of − 10 diopters ; with this, though the field is much curved, and good definition can only be obtained in the centre, the effect is quite good.

It will be realised that the substitution of oil for air between the front lens and the cover-glass is optically equivalent to the thickening of the cover-glass so as to fill the whole space between the object and the front lens : it might be expected, therefore, after what has been said, that the power of the additional lens required would be considerable ; and I doubt whether the effect could be obtained with a 1/6th-in., except perhaps with one of very short working distance.

The advent of the Zeiss 1/7th-in. oil-immersion drew attention to the better resolution given by an oil-immersion over that given by a dry objective of the same aperture ; but I did not expect that this would hold good with such an arrangement as that here described. I was much surprised, therefore, to find that it was possible to resolve *A. Lindheimeri* with a solid axial cone of illumination, the longitudinal and transverse striae being quite plain with a compensating eyepiece 16·5. In this specimen the striae run about 70,000 to the inch, and it is a very severe test, under the conditions of illumination mentioned, for any dry lens ; it is, of course, too hard for the 6 mm. Holos in its dry state, the aperture being insufficient. The introduction of the convex lens increases the N.A. to about 0·89 ; but I think it is safe to say that no dry lens of this aperture would effect the resolution with central light, though a much smaller aperture will suffice with oblique light. In this case, then, the conversion to an oil-immersion affords a distinct gain.

I have also tried to effect the conversion in the case of a Holos 4 mm. of N.A. 0·95 ; but in this case it was impossible, even with lenses of a total power of 18 diopters, which is far too powerful, and upsets the objective altogether.

This application of the additional lens, therefore, I think is of theoretical interest, but hardly of practical value.

I think that this device of the additional lens is worthy of extended trial, both for the purpose of correcting for the thickness of the cover-glass, and for the conversion of an oil-immersion into a water-immersion. I shall be gratified if it should prove of use to any one in practical work, and should be glad to hear that some one has taken it up.

NOTES ON DIATOM STRUCTURE.

By A. A. C. Eliot Merlin, F.R.M.S.

(*Read April 27th*, 1915.)

I venture to bring to your notice a very beautiful form of tertiary structure which I have recently found on a variety of *Aulacodiscus Comberi* from Oamaru. The valve is on a styrax type-slide of 230 forms from that locality and is covered with a network of dark, well-defined secondaries, except on the parts occupied by the large primaries. Each of the dark secondaries has been found to be split up into three or four parts by a bright cross-bar arrangement. This structure requires a good oil-immersion objective and a very considerable magnification to render it readily discernible, but it is in no way a glimpse object, and when well seen reminds one of the bridges of bright matter that are frequently observable crossing the umbrae of sunspots. Photograph No. 1 exhibits clear indications of the structure in question, × 2,150 diameters, although it cannot be photographed as plainly as it can be demonstrated visually. Incidentally the photograph serves to prove the fact that with a power of 2,150 diameters there is no excess of "empty magnification," when employing a good lens of 1·4 N.A., for few will comfortably see the structure therein without the aid of a low-power magnifier.*

Two other photographs are sent herewith for your inspection. These were secured under the following circumstances. Mr. Nelson wrote to me that he had discovered that *Coscinodiscus Simbirskii*, which with ordinary transmitted light resembles *Coscinodiscus asteromphalus*, looks like *Actinoptychus splendens* when

* The photographs referred to in this paper contain details of such a nature that only a drawing could adequately represent them for purposes of reproduction.

examined with dark-ground illumination and a rather small stop. This led me to search my Coscinodiscus genus circle slide for the diatom mentioned. Although this could not be found, another form was noted appearing with transmitted light as in photograph No. 2 (× 295), while with dark-ground illumination a beautiful radiating structure, somewhat resembling *A. heliopelta*, was revealed, which photograph No. 3, taken at the same magnification, inadequately represents. Print No. 2 fails to show a fine dotted structure which exists all over the valve and can be detected in parts of No. 3. Print No. 2 should make the identification of this specimen easy from its very marked peculiarities.* These photographs were taken with a 16-mm. apochromat of 0·35 N.A. and a × 6 projection eyepiece.

In connection with diatoms as test-objects there is an interesting point, to me at least, on which I have been able to find no definite information in the microscopical works in my possession. I am alluding to the exact period during which the fine structure of the diatom valve was first employed as a test-object. Are we approaching the centenary of its discovery, a discovery which has perhaps influenced more than any other the progress towards perfection of the modern microscope stand and its optical parts ? The oldest work on the microscope in my library is the *Micrographia Restaurata*, published in 1745.† This makes no mention of diatoms, so that it may be taken for granted that Dr. Hooke did not include "diatom-dotting" amongst his "Wonderful Discoveries by the Microscope" therein detailed. George Adams published the fourth edition of his *Micrographia Illustrata* in 1771 and also failed to include diatoms amongst the numerous objects described in his interesting book, although many quaint aquatic organisms are dealt with at considerable length, even including "a new sort of animalcula found in an infusion of

* *C. Ludovicianus* (Rattray) from Jutland.

† Dr. Robert Hooke, M.A., F.R.S. (1635–1703), *Micrographia, or some Physiological Descriptions of Minute Bodies made by Magnifying Glasses, with Observations and Inquiries thereupon.* The first edition was published in London, 1665.

blue-bottles." We may thus assume that diatoms had not at that period appeared on the scene to trouble the optician "at the Sign of Tycho Brahe's Head, No. 60, in Fleet Street, London." Then who was the first man to dot the first diatom ? * Possibly Dr. Goring, who, "is said to have discovered that the structure of certain bodies could be readily seen in some microscopes and not in others. These bodies he named test-objects; he then examined these tests with the achromatic combination before noticed, and was led to the discovery of the fact that the penetrating power of the microscope depends upon its angle of aperture" (*vide* Quekett's *Practical Treatise on the Use of the Microscope*, second edition, p. 38).† Be this as it may, several test diatoms are beautifully figured on Pl. 9 of Quekett's book, and it is instructive to note that *P. angulatum* shown therein is the Humber form with smoothly rounded outline and not the species now known as *P. quadratum*, which, I am told, was the original true *P. angulatum* as first found and named. Of course "diatom-dotting" was far advanced in Quekett's time. He recommends the *Navicula hippocampus* as an excellent test for a 1/4th-inch objective-glass, stating that it should "show distinctly both sets of lines or dots by oblique illumination." The younger members of this club may not realise that first-class 1/4th-inch objectives made in 1850 have apertures slightly exceeding 0·7 N.A. and will cleanly and clearly dot *P. angulatum* with axial critical

* Extract from Messrs. Sollitt & Harrison's paper read before the British Association at Hull, 1853:

"We in Hull first discovered the delicate markings on their silicious coverings and pointed them out to others as the proper tests for lenses. The first of the Diatomaceae on which the lines were seen was the *Navicula hippocampus* of Ehrenberg. . . . This discovery was made early in 1841, when specimens were sent to the Microscopical Society of London . . . also to Mr. Smith, Mr. Ross, Messrs. Powell & Lealand. M. Nachet in Paris and Professor Baily in America, the whole of whom at once saw the excellency of those objects as tests for the microscope. Indeed they are without doubt to the microscope what the close double stars are to the telescope."—E. M. Nelson.

† First edition published 1848.

illumination, but such lenses were much more expensive than those made to-day of equal, or superior, optical performance. Still, it is as well to bear in mind that in 1850 thoroughly well-corrected dry achromatic lenses up to 0·90 N.A. were obtainable (Powell's 1/16th-inch of that date has the last-mentioned aperture), and were capable of resolving most of the present well-known tests with the exception of the *A. pellucida*, this being first resolved (according to Dr. Carpenter) by one of Powell & Lealand's water-immersion objectives which that firm commenced constructing in 1868.

A NOTE ON THE SLIDES OF FISSIDENTACEAE IN THE Q.M.C. CABINET.

By G. T. Harris.

(*Read May 25th*, 1915.)

Communicated by Clarence J. H. Sidwell, F.R.M.S.

In Dixon's *Student's Handbook of British Mosses* the Fissidentaceae of Great Britain comprise fourteen species and about five well-marked varieties. Of these fourteen species eight are represented in the Cabinet of the Quekett Microscopical Club, and of these eight four at least are rare, and several very rare. *Fissidens exilis* is the smallest of our native species and is often found accidentally among some gathering of quite another moss when examination takes place at home. There is no difficulty in recognising it owing to its minute size and non-bordered leaves. *Fissidens viridulus* is very slightly larger than *exilis*, but has the leaves distinctly bordered with a narrow cartilaginous border, which is usually lost at the apex; the variety *Lylei*, however, may be confused with *exilis*, as it is very minute and has no border *except on the sheathing laminae*, indeed it has been made a separate species by some authors. It has been proposed to unite the species *viridulus*, *pusillus*, and *incurvus* under one specific type, as intermediate states are often met with. *Fissidens incurvus* var. *tamarindifolius* also at one time had specific rank, but is now generally accepted as a variety of *incurvus*. It is usually found sterile and has a quite distinct facies when growing, that readily assures it recognition.

On closer examination the broad, distant leaves are quite distinctive.

Fissidens algarvicus (Solms.) was first recorded for the British Isles by Mr. G. B. Savery at Silverton, S. Devon. It has later been found near Cheltenham. Originally found in Portugal, it appears to reach in England its most northerly limit. It is interesting to note that a very closely allied species, *Fissidens Orrii* (Lindb.) (= *F. tequendamensis*, Mitt.), was recorded in 1854 from Dublin. Dr. Braithwaite pointed out the suspicious proximity to the locality of the Glasnevin Botanic Gardens, and certainly the species so far has not been refound, so is excluded from the British Moss Flora.

Fissidens bryoides is at once the commonest and most variable of our species. The border is usually strong and continuous to the apex, where are a few minute denticulations. It varies considerably in size from a quarter of an inch to an inch or more in height. It is densely gregarious, and it is not difficult to recognise it by its general habit and habitat after a little experience. The form *inconstans* has the fruit sometimes terminal, at other times lateral, but its leaves and structure remain fairly true to type.

Fissidens Curnowii was originally described by Schimper as a variety of *bryoides* under the name *caespitans*, but Mitten later raised it to specific rank as *Fissidens Curnowii* in honour of W. Curnow, who apparently first discovered it in England in 1868. Mr. H. N. Dixon in his *Student's Handbook of British Mosses* gives it an intermediate position as a sub-species. It is a rare species and the few records for it are from near the sea in the south-west of England, though it has been recorded from comparatively northern stations.

Both Curnow and Ralfs describe their localities as aquatic. My locality in Sidmouth is a damp, not wet, sandstone cave,

and I should scarcely have regarded it as an aquatic species comparable with *rivularis* or *crassipes*. It is a handsome moss, usually fruiting profusely, and thickly matted with purple radicles, though these are not so abundantly developed in the young plants as in the older.

Fissidens rivularis, a truly aquatic moss, was originally found by Mr. E. M. Holmes at Hastings in 1884, and this has hitherto been the only British station. Some time ago I was fortunate in adding a second station near Sidmouth, which appears to be identical in physical conditions with Mr. Holmes's original one. It occurs on rocks kept constantly wet by dripping water, and in deep shade. Often it is quite hidden by an overgrowth of some freshwater algae, and the fruit appears to be rare. The broad yellow nerve and border, with its aquatic habitat, sufficiently indicate it.

Fissidens polyphyllus is another more or less aquatic species. The slide of this moss was already in the Quekett Microscopical Club collection, and was sent to me with other slides of mosses for verification by the Hon. Curator, Mr. Sidwell. No locality is given, but it occurs very rarely in North Wales, Devon and Cornwall. The fruit appears to be extremely rare, and has perhaps only once been found, by M. Camus near St. Rivoal in France. It is always barren in England, or at least has not been found fruiting.

Fissidens taxifolius is a very common species on stiff argillaceous soils, and is one of the most easily recognised of the Fissidentaceae. These comprise the various species of Fissidens at present represented in the collection of the Quekett Microscopical Club. I am hoping, however, that it may be possible to add other species at a later date, possibly to make up the entire series.

The genus is a very natural and distinctive one owing to

the bifarious arrangement of the leaves, and especially to the curious sheathing laminae, so characteristic of the Fissidentaceae. Many theories have been advanced to account for the conduplication, and if the one that regards it as being originally a stipule that has become adnate to the nerve by one of its margins is the correct theory it certainly opens up a very interesting vista of evolution.

FURTHER NOTES ON THE CULTIVATION OF PLASMODIA OF *BADHAMIA UTRICULARIS*.

By A. E. Hilton.

(*Read May 25th*, 1915.)

A year ago I called your attention to a method of cultivating plasmodia of *Badhamia utricularis* on bread, with occasional applications of a solution of ammonium phosphate and cane sugar; and my paper on the subject appears in the Journal for November last. In the discussion which followed the reading of the paper two points were raised which I could not reply to without further investigation.

One of these was an inquiry by our Secretary as to whether plasmodia of this particular species of Mycetozoa can be obtained by cultivation of spores; the answer to which is, that it is possible, but not always easy. In the *Journal of Botany* for January 1901 there is an account of an experiment on the point, made by the late Mr. Arthur Lister, which ended successfully after difficulties by the way had been overcome. In that experiment spores of *B. utricularis* were moistened with boiled water, and spread on slices of scalded fungus (Stereum). In six weeks' time, after various vicissitudes, minute plasmodia were seen under a microscope with a 2/5th-in. objective, and in another fortnight or so a larger plasmodium was obtained, which afterwards grew to a considerable size, part being dried off into sclerotium for subsequent use, and the remainder forming sporangia. It is to be noticed that in using Stereum Mr. Lister relied upon natural rather than artificial food, the scalding of the fungus being no doubt for the purpose of destroying any organisms likely to upset the experiment.

The other question was raised by our President, who inquired whether plasmodia fed by the artificial method introduced by me could form sporangia. This point was clearly of importance, involving as it did the crucial question as to whether, and to what extent, such feeding affected the specific integrity of

the fundamental protoplasm. Again I found that the answer to the question was in the affirmative, but with certain reservations. On February 19th last a plasmodium of *B. utricularis* was started by reviving a fragment of sclerotium, and this I treated, throughout the whole course of its development, with nothing but bread and water, and the chemical solution, including calcium phosphate, which I added at Mr. Grundy's suggestion, with a view to supplying the lime usually found in the sporangia of Mycetozoa classified as Calcarineae. For some weeks, owing to low temperatures, growth was slow, but on the weather becoming warmer, it increased considerably, and finally on May 5th, when the atmosphere became close, with a thunderstorm impending, the plasmodium changed into a quantity of sporangia.

There are, however, striking differences between these sporangia and those produced in natural conditions. The shape is similar, but instead of being of the usual cinereous hue, they are mostly a dull purple-black; others being of a cinnamon-brown colour, and some of a pale biscuit tint. All are sprinkled with white crystalline particles. The sporangium walls, usually very thin and fragile, are hard, thick, and chippy; and there is no distinguishable capillitium. Stranger still, the sporangia are only about half the ordinary diameter; in other words, about one-eighth of the usual size. The spores, generally bright brown and spinulose, are smooth and almost colourless; but they are of the usual dimensions, if not, on the average, slightly larger, and in other respects appear to be perfectly normal.

The characters on which the classification is based are thus altered in nearly every particular; the only permanent feature, if there is one, being the specific spore-plasm. The result shows what remarkable powers of adaptation the plasm possesses, how precarious the present basis of classification really is, and how impossible it is to define a species without a deeper knowledge than we yet possess of the specific character of the plasm on which all the activities of physical life depend.

HYDRODICTYON RETICULATUM.

By James Burton.

(*Read May 25th*, 1915.)

Last autumn I had the good fortune to obtain the freshwater alga known as the Water-net, *Hydrodictyon reticulatum*, or *utriculatum*, for both names are used.

It occurred in immense quantity in the lake in Kew Gardens and was brought to my notice by Mr. Traviss, who at the "Gossip" meeting in September told me there was a plant in great amount in the lake at Kew, and that it was like one of those loofahs used in baths—it seemed to me a capital description, and I at once realised that it was Hydrodictyon, and visited the scene next day. Prof. West says it is a very rare plant in Britain, but several authors say it is found fairly frequently in the south and south-east of England. I do not know of it having been found at any of our excursions, and though probably known by name to many, it is most likely that few have seen it. I have a page, evidently part of an article, in Dr. Cooke's handwriting which gives some information about it. He says: "The Water-net is one of the earliest enumerated of the Freshwater Algae in Britain. Its characteristic form enables figures to be instantly recognised, and thus we are without doubt able to assert its presence in 1691, when it was figured in Plukenet's *Alma Gestum* (Pl. 24, f. 2) and again by Bobart in the 3rd vol. of Morison's *Hortus Oxoniensis* in 1699. Ray includes it in his "Synopsis" in 1724 as *Conferva reticulata*, and says that it was found at that time in ditches, about Westminster and Hounslow." Dr. Cooke then gives a number of instances in which it is referred to by various writers, including Hassall in 1845. He then says: "Recent localities have not been recorded, in fact it is very desirable that we should know the present stations of such an easily recognised plant, which this year appeared in such quantities in a small pond in the pleasure ground at Kew Gardens

at the end of June, and scarce a fragment to be seen in the middle of July." Unfortunately there my page comes to an abrupt end, but as there are several interesting points about this alga, it may be worth while bringing them to the notice of the Club.

Owing to various characteristics which are not found in any other alga, the genus Hydrodictyon has a sub-family to itself and there is only one species. It consists of a saccate, net-like object which ranges in size from very small, almost microscopic dimensions up to a length of several inches, four, six and even more. The cells of which the net is formed also vary very much in size; in the young ones they are quite minute, when first recognisable from 8 to 10 μ in diameter only, but enlarge so much in growth as sometimes to reach a length of 1 cm., say two-fifths of an inch. The cells are approximately cylindrical in shape and are arranged with their ends in contact, usually three meeting at such an angle as to form typically hexagonal meshes, but meshes with fewer or more boundary cells are not uncommon. They have a somewhat thick cell-wall, and inside a layer of protoplasm, in which the green chlorophyll is diffused, not collected into definite chloroplasts as is usual in algae.

The centre is filled with cell-sap. There are very numerous and quite typical pyrenoids in the protoplasm, each consisting of a central body, with a layer of starch grains on the outside; these may be considered reserve food material. At the commencement of reproduction they disappear, and are obviously used up during the process. There is also a quantity of fine starch grains in the protoplasm, these being used for the purposes of life and growth. Many nuclei are present in each cell.

The first point to notice is that the organism as a whole is what is known as a *coenobium*; it is, perhaps something more than what is known as a colony, because the individual cells are actually attached to one another, and form an association, but certainly they are not greatly dependent on each other. Each component cell is an individual, and carries on its living functions independently; for its own benefit solely it assimilates, respires and reproduces, and were it separated from its fellows would still be able to exist. We might then be inclined to inquire what advantage the plant gains from the association of so many units. One advantage is, that if the composing cells

were separate, and sank to the bottom of the water, they would be liable to become overwhelmed in the mud and debris, while in their present condition they would rest on the bottom without danger of being covered up. It may also be noticed that an organism formed like the water-net, when it is in active life under the influence of warmth and light, excretes gas, and forms bubbles, which are entangled in the meshes and float the whole colony to the surface where it obtains better light and purer water. Another advantage may be that the separate cells, being for a time very small, would be liable to be taken as food by various small aquatic animals, a fate to which they are much less subject when combined into a larger body. Many of the filamentous algae not usually looked upon as composed of individuals, as coenobia in fact, are so in reality. This is the case, for instance, with the well-known Spirogyra; here each cell of the filament if separated would be able to carry on its vital functions, and probably the chief advantage it gains from its form is something of the kind already mentioned.

But this brings me to the next point of interest in the water-net. In Spirogyra and almost all other freshwater algae, multiplication very largely takes place—in many species there is no other method of propagation—by means of what we may call vegetative reproduction. A cell grows till it reaches its maximum size, a wall is then formed across it and the one large mature cell becomes two smaller young ones which gradually grow, and the process is repeated. Now in Hydrodictyon there is no division of a cell. You may examine any number of plants, each consisting of perhaps thousands of cells, and you will never find one undergoing cell-division. The cell begins quite small and grows till it reaches what is a very large size for such an organism, but it never gives rise in this way to another. From this a singular result arises. The net is born, as we may say, with a given number of cells, and through its life it consists of only the same number and indeed of the identical ones which it had originally. If owing to injury a part of the net is destroyed, it is not replaced, the deficiency cannot be made good.

Another unique fact is the method of reproduction: no other alga has the same in detail. In the non-sexual method—which is, I think, the most usual and is indeed the only kind of which I have had actual experience—a small complete net consisting,

it may be, of some thousands of cells, is formed inside each of the members of the original net, which is reproducing. The process takes place in this way. The pyrenoids disappear and the protoplasm collects round each of the numerous nuclei, these then divide repeatedly, until the whole becomes an enormous number of spherical zoogonidia; there may be from 7,000 to 20,000 of them in a single cell. In this they "swarm," as it is called, *i.e.* they have a tremulous motion, not moving from place to place to any extent, but just vibrating. There is some uncertainty as to whether the gonidia have cilia; one account says they have four, most say two, and one account—I think it is in Kerner—says they are not completely separated from one another, but remain attached by a thread of protoplasm. I do not think this is correct and believe they are actually separate for a time, they then become oval instead of spherical and attach themselves to one another by the ends, and gradually in each mother-cell a complete young one is thus formed.

In the meantime the mother-cell wall gelatinises, and this goes on so that by the time the young net is complete there is scarcely any of the wall remaining, and soon it is entirely diffused and the young one is set free. Some of the books tell us that a slit is formed in the mother-cell and the young net escapes through that, but I have not seen this occur, and think that the description applies to another circumstance—namely, the sexual reproduction. This I have not observed, but stated shortly the method is as follows: A much larger number of minute reproductive bodies than in the previous case is formed. From 30,000 to 100,000 of them arise in the parent cell; each of these gametes has either two or four cilia. They issue from the parent cell through a slit in the wall, enclosed in a vesicle formed from the inner layer of the cell, and, becoming free in the water, conjugate in pairs. The resulting zygospore sinks to the bottom. It may germinate at once, but usually divides into two or four parts which become resting spores—they are known from their shape as polyhedra; after some months they give rise indirectly to small nets, which then give rise to larger ones of the usual character. It may be noticed that there is no true sexuality in the cells—or individuals—of which the net is formed. Any cell may give rise to either sexual or non-sexual reproduction according to circumstances. Klebs (I think it is) has stated

that non-sexual reproduction occurs when the water is clear and there is abundance of chemical food material present with appropriate temperature and light—in fact with favourable vegetative conditions—while under less favourable conditions, and with the presence of organic matter, decaying plants and so on, in the water, there is a tendency for sexual reproduction to take place. And he states that either condition may be readily brought about at will, with plants grown under observation.

Perhaps not the least interesting fact about Hydrodictyon is the manner of its occasional appearances. After being plentiful on one occasion it will totally disappear, and for perhaps several years nothing will be seen of it. Then again, owing to no particular cause which is understood, it has another outbreak, and the water from which it has been absent for long is again filled with it. These outbreaks are known in some parts as the "breaking of the meres," and by other similar terms. I knew that in times past Hydrodictyon frequently appeared in the lake in Kew Gardens and for many years—more than thirty, I believe—looked out for it in vain. During all this time I only found one very small and unsatisfactory specimen. Then last autumn a tremendous outbreak occurred, the water was so full of it that at the lee end of the lake the Hydrodictyon was massed together to such an extent that it was impossible to get good examples. Two boats were on the water, with men gathering it in with rakes and piling it in heaps on the shore. In rather less than four weeks I again visited Kew, and though diligent search at every part of the lake was made, not a single specimen could be found. Prof. West in speaking of this phenomenon in regard to various other algae says "they usually consist of species that are normally present in the waters." But that can hardly be said in this case; normally it is impossible to find an example of Hydrodictyon in the lake at Kew.

Personally I cannot suggest any better explanation of the cause of the phenomenon than I gave once before. Speaking of a similar outbreak of another alga it was said: "Of course in some form they must always be present in the places in which they occasionally appear so abundantly; but the causes which enable them to multiply in this manner seem to be unknown. It cannot be a seasonal increase alone, such as we have in flowering plants, which at the proper time develop and then die

away. In that case the 'breaking of the meres' would be an annual occurrence, or nearly so, with more tendency to regularity than it seems to have. Clearly there must be some simultaneous occurrence of several favourable circumstances which does not frequently arise: possibly some special type of weather and some narrow range of temperature at a particular season would be factors in the required conditions."

VARIOUS INSECT STRUCTURES.

By Edward M. Nelson, F.R.M.S.

(*Read May 25th*, 1915.)

The wing of *Agrion pulchellum* (Neuroptera) is not only a wonderful, but a particularly interesting microscopical object. The membrane, which in life reflects beautiful colours, is double, each part being bordered by a stout rim edged with formidable saw-like teeth. The surface of the wing is divided into compartments by nervures which are peculiar; for the transverse bars, as well as four of the longitudinal bars, have on one edge thorns just like those on a sloe-bush, and on the other edge saw-like teeth; there are three other longitudinal ribs, which have saw-like teeth on one edge and very fine teeth on the other, but no thorns.

This beautiful microscopical object forms an excellent test for low powers, "loups" or simple microscopes.

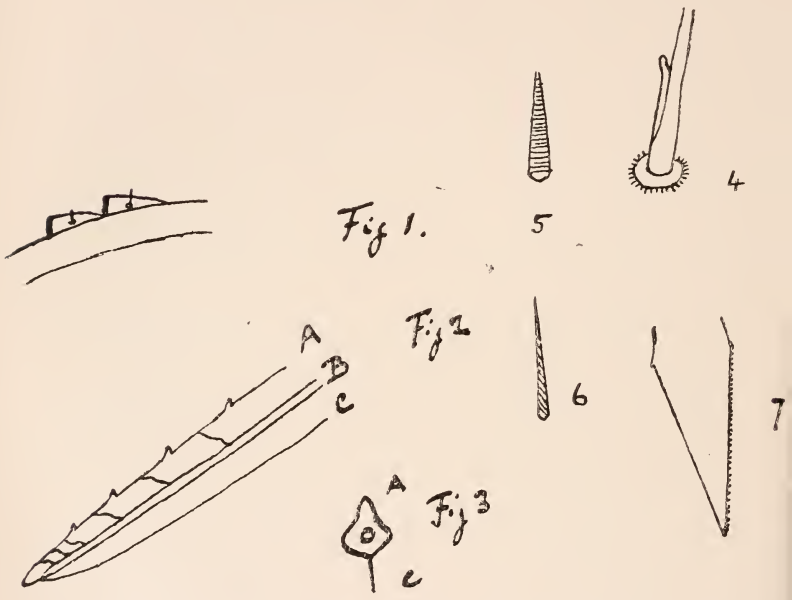
At one part on the edge of the wing there is a dark-coloured compartment, inappropriately called the "stigma." This really is a pocket, the two membranes being separated from one another at this point by some brown cellular tissue, the saw-edged borders of the membranes being kept apart, thus forming an opening. Obviously, then, the "stigma" is an apparatus for producing a sound, much in the same way as the "bull roarer" of our childhood. The "stigma" can be seen readily by the naked eye, as it measures 1·1 mm. × 0·5 mm.

If we replace the low power by a 1/2 inch, a careful examination of the border of the wing reveals a delicate hair between the teeth of the saw (fig. 1).

These hairs are minute, the largest one found measured only 23 μ in length and 2 μ in breadth; but on other species of Dragonflies they are larger and more easy to demonstrate. These hairs spring out of circular rings, after the manner of most hairs on insects, and not like the small ones on the membrane of the blow-fly's tongue, which have no rings. While on this subject of

insects hairs, a careful examination of the small hairs upon the wing of a wasp will show that they are twisted like the tusk of a narwhal (fig. 6).

The hairs on a bee's wing are somewhat similar, but not so much twisted, while they have no ring. Those on the wing of a saw-fly (Tenthredo) issue from a boss. The hairs on the ovipositor of Phalangia are more interesting. This ovipositor has some thirty or forty white and brown transverse stripes; the hairs upon it are of the ordinary kind with a ringed base,



except those upon the two last terminal stripes, where the hairs are larger and the ringed base is ornamented with a circle of very minute hairs; the hair itself is tubular and has a filamentous end. At the side of these hairs there is a sort of minute prong, which might be thought a hook, but is, I think, a cut or opening in the side of the hair (fig. 4, termination of hair not drawn). At the end of each of the two lobes of the ovipositor is a small boss covered with small hairs. These hairs have no ring bases and are blunt-ended, probably open at the top; but they have internal ring (not spiral) structure somewhat like an

artery (fig. 5). A 1/4th inch will be necessary to demonstrate these structures. The saw on the wing of Agrion is a comparatively bold structure, but if we examine the mandibles of a gad-fly (*Tabanus bovinus*) we shall find upon one edge the most wonderful saw in the world, having ten to sixteen thousand teeth per inch on it, while the other edge is the keenest blade in existence (fig. 7). As a point of "microscopy" these teeth on the saw on the the lancets or mandibles of this insect form the most delicate optical test I know. This is a matter of some importance, as Podura test-scales are now not to be had—for, sad to say, one may pay 20*s.* for a slide of Podura scales and not find a single test-scale upon it! If any member of the Club has an objective that will show these saw-like teeth with a large or full cone he should take great care of it, as it may be some time before he finds another that will do so. A $1\frac{1}{2}$ inch * that will demonstrate these teeth at the point of the mandible with axial illumination must be a good lens. This test, however, is not confined to low powers, for high powers such as a 1/4th or a 1/6th that will show the teeth with a large working aperture cannot have much wrong with them. As the aperture of the substage condenser is opened a point will be found when, owing to spherical aberration in the objective, the image of the teeth will vanish suddenly. This test rivals in sensitiveness all others with which I am acquainted, and it is scarcely necessary to add that a precise adjustment of tube length is necessary; but it is important to bear in mind that with a small or moderate sized cone it is no test at all.

The teeth are coarser at the point, where they count 10,000 per inch, and finer at the base of the mandible, where they count 16,000 per inch. Those on the mandible of *Haematopoda pluvialis* are still finer and count from 15,600 to 19,200 per inch. The stout hairs on the palpi of this insect issue from a delicate cup. The hairs on the wing of *Trichopteryx atomaria* have secondary hairs on them; a secondary hair measured in length 1·1 μ, thickness 0·18 $\mu = \frac{1}{141000}$ inch. This beautiful microscopical object cannot be seen with an objective of less than 0·58 N.A. These few instances are mentioned to show that a critical examination of the hairs of insects is not only a

* Some $1\frac{1}{2}$ inches are engraved 2 inches; such lenses should also show them.

useful, but also a fascinating branch of microscopical study. We will now pass on for a moment to the *Vespa crabro*, or hornet. If its sting be examined with a 2/3rd inch objective the barbs, A, fig. 2, will be seen; B is a tube, and C a razor blade. Fig. 3 shows the sting in section. The fine tubules, three below the last barb and one below each of the others, will be seen. The breadth of the sting in fig. 2 is 110 μ, the width of the razor blade 33 μ, the length of a barb 17 μ, the length of a tubule 25 μ, and its width 4·2 μ. If the sting happens to be well placed the exit pore of a tubule may be caught. It is probable that these stings are homologous with the saws in the ovipositors of insects. Instead of barbs there are bold saw-like teeth, which, unlike those in a carpenter's saw, go round the side of the saw—the holes for the emission of lubricating or poisonous fluids are numerous and much easier noted than those on the sting of a hornet. The ovipositor of a dragon-fly is a good example.

In conclusion, I would draw your attention to the pygidium of a flea. If the right- and left-hand edges be examined a hole will be found; this is an Eustachian tube. The apparatus corresponds to the drum of an ear, and must like it have an air passage to equalise the pressure on either side. Now look at the base of the haltere in a blow-fly, where a similar tube will be easily seen.

THE DETERMINATION OF MINERALS UNDER THE MICROSCOPE BY MEANS OF THEIR OPTICAL CHARACTERS.*

By J. W. Evans, D.Sc., LL.B. (London),
of the Imperial College of Science and Technology, and Birkbeck College, University of London.

(*Read June 22nd*, 1915.)

Communicated by the Hon. Editor.

Plates 35–37.

A petrological microscope is not merely employed for the study of details too small to be seen by the unaided eye, it is also an instrument for the investigation of the optical properties of minerals, by means of which they may be distinguished from one another.

Rotation of Nicols or Stage.—For this purpose the microscope must be so constructed that the minerals can be examined between crossed nicols. A Nicol's prism or *nicol* permits only light vibrating in a particular direction to pass. Two nicols are said to be *crossed* when these directions of vibration are at right angles to each other. It is also necessary that either the stage or the nicols shall be capable of rotation round the microscope axis. For many reasons the rotation of the nicols, while the stage remains stationary, is to be preferred; and when an immersion lens is employed with loose material, it is essential that there should be no relative movement between the stage and objective. The mechanical difficulties of construction in instruments of this type add, however, considerably to the expense, with the result that in the majority of petrological microscopes in use the nicols are fixed, while the stage rotates. I have, accordingly, assumed throughout that such an instru-

* A brief communication to the Geologists' Association on similar lines was made by the author in 1909 (see *Proc. Geol. Assoc.*, vol. xxi., 1909, pp. 79–94). The Quekett Microscopical Club is indebted to the Geologists' Association for their courteous permission to use the blocks illustrating this paper.

ment is employed. At the same time the complication of the phenomena caused by the rotation of the object renders a systematic procedure, such as I shall describe, very desirable, if mistakes are to be avoided.

Centring.—In such an instrument an arrangement for centring, by which the axis of the microscope can be adjusted so that it may pass through the centre of the stage, is absolutely necessary. The centring may be carried out by placing a rock-slice in focus under the microscope, noticing the point round which the object seems to rotate, and bringing this to the centre of the field by means of the centring screws.

Nose-piece.—The mechanism for centring should be applied to the nose-piece and not to the stage, since it is the former which is most liable to be displaced, especially if a double or triple nose-piece for interchanging objectives be employed. The use of a clutch, first employed, I believe, by Nachet, by which objectives can be rapidly attached or removed, is preferable. Recently a lateral sliding arrangement has been introduced, but I do not think that it possesses any points of superiority over the clutch.

Movements of One Nicol.—One or both nicols should be capable of separate rotation, and one at least should be capable of being rapidly thrown out of the course of the light so that the observation may be made with one nicol only. The nicol that remains in position should be so placed that it allows light vibrating right and left to pass, for with the usual disposition of the mirror the light reflected from it is polarised so that more of it already vibrates in this than in other directions. There is consequently an appreciable saving of light with this position of the nicol.*

It is usual to remove the upper nicol or analyser, but F. E. Wright recommends the removal of the lower nicol or polariser. This has the advantage that the field is not affected in focus or position, when the nicol is moved in or taken out.

* To ascertain in what direction light traversing a nicol vibrates, the nicol should be inserted alone and a rock-slice containing biotite flakes showing strong pleochroism placed on the stage and rotated till a flake is in the position of maximum darkness. The direction of the cleavage of this flake will then be parallel to that of the vibration of the nicol.

The upper nicol usually slides in and out of the lower part of the tube above the objective. This has the advantage of not obstructing the field, but there are two objections to this plan. In the first place the nicol cannot, as usually constructed, be rotated, and secondly, it does not allow of the insertion of a quartz wedge in focus. For this reason the upper nicol is sometimes placed above the eye-piece. In this case it should be thrown in or out by means of a hinge. The common arrangement by which it is removed altogether results in loss of time in adjustment when it is replaced. The nicol that rotates should be provided with catches or "clicks" to arrest its movement in the crossed position, and in that at right angles to it, in which its direction of vibration is *parallel* to that of the other nicol.

Cross Wires.—The cross wires will be parallel to the directions of vibration of light traversing the nicols respectively when in their normal position.

The cross wires should not be spider lines, which are easily broken by the insertion of the quartz wedge or other accessories, but should be ruled on a glass plate. As this is apt to get covered with dust, the eye-piece should be made to screw apart immediately above the plate so that it may be easily cleaned.

Slots.—The microscope should be provided with one or more slots for the insertion of various accessories. In this country slots are placed diagonally to the cross wires. On the Continent, however, they are sometimes right and left, and accessories connected with polarization effects, such as quartz wedges, gypsum plate, or mica steps, must be constructed accordingly. This is a matter that requires attention in buying and working with foreign microscopes. The slot is usually placed immediately above the objective. Wright, however, prefers to have it below the stage (but naturally above the lower nicol), so that the insertion of a plate or wedge, like that of the lower nicol referred to above, does not affect the field. Another course is to have the slot at the focus of the eye-piece, in which case the upper nicol must be placed above the eye-piece. This arrangement has the advantage that a quartz wedge, or other accessory, placed in the slot is in focus. The same result can also be obtained with a slot below the stage, if the condenser be placed in position and slightly lowered.

Means should be provided to close the slot, when not in use.

Fine Adjustment.—The fine-adjustment screw should be graduated on its circumference so as to show the number of microns by which the microscope is raised or depressed. A micron is the thousandth part of a millimetre and is the most convenient unit of length for microscopical purposes. A complete turn of the screw will usually correspond to 500 microns, and in that case a scale parallel to the axis should be provided, divided into half millimetres, so that by means of the double graduation comparatively large movements may be accurately measured.

Illumination.—The best illumination is that from the sky. If artificial light must be resorted to, a gas mantle provided with a cylinder of ground or milk-white glass, or a small arc light similarly treated, should be employed. If, however, the illumination is very strong, the lower nicol may be injured by overheating. If there is any danger of this, a suitable glass vessel containing water may be interposed.

Objectives.—Although a 1-in. objective is used for most purposes, a lower power is convenient in the case of rocks of coarse texture, while for very fine structures and minute crystals and inclusions a 1/4th-in. or still higher power must be employed. I have myself found a twelfth very useful.

These close objectives are also required for the simultaneous examination of different directions in a crystal, a subject I shall deal with later.

Rock-slices.—A good rock-slice should range between twenty and thirty microns in thickness, but with comparatively large transparent minerals much thicker sections may usefully be employed, while those with fine structures or which are comparatively opaque should be as thin as they can be made. It is important that a section should be as uniform in thickness as possible,

It is preferable that a rock-slice intended for research should have no cover-glass and that its surface and sides should be free from Canada balsam. It may then be covered in turn by liquids with different refractive indices (see p. 626) or subjected to microchemical tests.

The Object-Image.

Under this heading I include all observations in which the object itself appears in focus in the field of the microscope.

Examination in Ordinary Light.—The crystal section should be brought into the centre of the field, so that it lies beneath the intersection of the cross wires, and the stage rotated till the index reading is zero. The outline and any other characteristic features should now be traced or sketched, surrounded by a circle representing the margin of the field, and a scale of microns with the numerical value of the magnification added. The scale is constructed with the assistance of an eye-piece micrometer calibrated from a stage micrometer. The position of the cross wires is shown by short radial lines drawn inwards from the circumference (figs. 1–3). The right end of the right and left cross wire is marked with 0° outside the circle, because it is the direction of the vibration of the nicol, when one only is inserted, and the positions of the other ends of the cross wires by 90°, 180° and 270°, in the same cyclical order as the graduations on the stage, which are usually contrary to those of the hands of a watch.

The stage is now rotated, and as the trace of a face, cleavage or other rectilineal marking, such as a line (representing a plane) of inclusions, comes into a position of parallelism with the right and left cross wire, the latter should be inserted in its new position in the sketch as an interrupted line across the field, and distinguished on its right extremity outside the circle by the index reading of the stage (figs. 1–3). As each line comes twice into the right and left position, it will have readings at both ends, which will differ by 180°. All these readings will follow each other in the sketch in their cyclical order.

Extinctions.—Both nicols are now inserted in the crossed position and the stage rotated. If the crystal section remain dark through a complete rotation, the crystal section is either isotropic or cut at right angles to the optic axis of a uniaxial crystal. If it continue uniformly faintly illuminated, it is at right angles to an optic axis of a biaxial crystal. Usually, however, it will be dark at four points in the rotation when the directions of vibration of light traversing the crystal section

are parallel to those of the nicols and therefore to the cross wires.*

These positions of darkness are known as *extinctions*, and they are distant 90° from one another. If the section is exactly at right angles to a plane of crystal symmetry or parallel to an axis of crystal symmetry, in which cases it is at right angles to a plane of optical symmetry, the position of extinction will be identical for all colours and will be characterised by complete darkness. At the same time the crystal outline will usually be symmetrical to the cross wires, which will now indicate the directions of vibration, both in the nicols and the crystal, for all colours. In such cases, the extinction is said to be *symmetrical*.

If, on the other hand, the section does not occupy such a position the extinction will be different for different colours, or, as it is usually expressed, is *dispersed*. Unless the dispersion be very small, there will never be complete darkness with white or other composite light, but it may always be obtained by employing monochromatic light.

There is usually some difficulty in determining the position of maximum darkness corresponding to the true position of extinction, even where there is no dispersion, or where monochromatic light is employed, and resort has been had to various methods of obtaining an exact result.

One of the simplest of these is to rotate the stage towards the position of extinction alternately from opposite cyclical directions and to note the readings on each side where the same degree of darkness has been obtained. The mean of several pairs of careful observations will approximate closely to the index reading corresponding to the true position of extinction.

In another method, which has been investigated in detail by F. E. Wright,† the crystal is first placed in the approximate position of extinction obtained in the manner already described, and then one of the nicols is rotated through a small but definite angle and the degree of illumination that results is carefully noted. The nicol is next rotated in the opposite direction through exactly the same angle on the other side of its normal position.

* According to one view of the direction of the vibration of light in crystals this is not strictly true; it is, however, in any case sufficiently accurate for practical purposes.

† *Am. Journ. Sci.*, Series IV., vol. xxvi., 1908, pp. 349–368, 379.

If the illumination in the two cases be the same, the supposed position of extinction is correct. If not, the nicol is restored to its original position, and the stage is rotated slightly towards the direction in which the darkness was the greater. The same test is then again applied, and, if necessary, the process is repeated, till the rotation of one nicol through equal angles in both directions produces the same result.

The angle through which the nicol must be rotated is that which will produce a faint illumination for rotation in one direction. It is usually between half a degree and two degrees. As a rule it would be sufficient if a graduation were provided showing a rotation of a nicol through $\frac{1}{2}$, 1 and $1\frac{1}{2}$ degrees.

Where the position of extinction is the same for all colours, this method may be applied either with monochromatic or white light, the latter being preferable, not only because the illumination is greater, but also because, when the true position of extinction has not been obtained, the two directions of rotation of a nicol give different interference colours.

Wright has devised a *bi-nicol ocular* in which the results of the rotation of two upper nicols in opposite directions may be observed simultaneously.* A similar effect is obtained by the insertion of plates of right- and left-handed quartz, which rotate the nicol through equal angles in opposite directions. This is the principle of the Bertrand eye-piece, but in its usual form the plate is so thick, 2·5 mm., that it rotates the light through a large angle, about 60° for sodium light and greater or less amounts for light with shorter or longer wave length. If it be reduced to a thickness of forty microns corresponding to a rotation of 1° for sodium light, much greater accuracy is obtained, both with monochromatic and white light.†

Wright's *bi-quartz wedge plate*, a combination of wedges and plates of quartz, enables a rotation of any convenient amount in opposite directions to be obtained.‡

In all these determinations greater accuracy can be secured by increasing the illumination, but care must be taken that the lower nicol is not injured by over-heating (see p. 600).

It is unnecessary to dwell here on the other methods which

* *Loc. cit.*, pp. 374–376, 379.

† *S. Nakamura*, *Centr. f. Min.*, 1905, pp. 267–279.

‡ *Am. Journ. Sci.*, Series IV., vol. xxvi., 1908, pp. 377–380.

have been introduced at different times for the same purpose, as few if any of them are so exact as those which have been described.

When the stage is in the exact position of extinction—in other words, when the directions of vibration in the crystal are parallel to those of the nicols and therefore to the cross wires—the position of the latter is indicated in the sketch by thick lines traversing the whole field, and the index reading is inserted on the right extremity of the right and left cross wire, while the other terminations of the cross wires are distinguished by the corresponding angular numbers differing by 90° (see fig. 1).

Pleochroism, etc.—The light vibrating parallel to each direction of vibration is differently affected by the structure of the crystal. The velocity of transmission of the vibrations parallel to one is greater than that of those parallel to the other and the index of refraction is consequently less in the case of the former. At the same time the absorption of light may differ considerably both in the colour selected and in amount. For an examination of these differences the crystal is observed with only one nicol in place, and the stage is rotated in turn into each of the positions in which a direction of vibration is parallel to the right and left cross wire. This, as we have seen (p. 598), should be the direction of vibration of the nicol that is retained. The surface of the mineral, whether it is rough or smooth, and its luminosity and colour are observed in each case and noted in the sketch at the right end of the thick line representing the corresponding direction of vibration.*

Sometimes the surface of the crystal is distinctly rougher in one position than in the other. This indicates that there is considerably more difference between the refractive index of the light vibrating parallel to the right and left direction and that of the medium in which the section is mounted (Canada balsam or whatever it may be) in the former case than in the latter. This phenomenon is well seen, when Canada balsam is the medium, in calcite and the carbonates isomorphic to it, as well as in the colourless micas. It causes a characteristic twinkling effect when the lower nicol is rapidly rotated.

Character of Directions of Vibration.—We now proceed to determine the *character* (or sign) of the extinctions or directions

* See fig. 1.

of vibration in the crystal section—that is to say, to ascertain which of these is the direction of vibration of light with the greater velocity, and which that of light with the less velocity. The character of the former direction of vibration or extinction is said to be fast (−) and that of the latter slow (+).

Relative Retardation.—We can also determine at the same time the amount of the *relative retardation*—in other words, the distance by which the slow-moving vibrations have lagged behind the faster. Both are delayed in traversing the section, but the former more than the latter. Relative retardation is usually measured in micro-millimetres or millionths of a millimetre. The character of any definite direction in a crystal section, *e.g.* one of its longer sides, is also said to be *fast*, or *slow*, according as it coincides or makes an angle of less than 45° with the fast, or the slow, directions of vibration, and to be *neutral* when it bisects the angle between them.

For the purpose of making these determinations the section is brought into a position of extinction and then the stage rotated through 45°, so that the directions of vibration in the section are diagonal to those in the nicols. This is known as the *diagonal position*. One of the directions of vibration in the section will then be parallel to the slot. To ascertain which it is, the stage is rotated through 45° till the direction which was parallel to the slot is in the right and left position, when the index reading will be that of the direction required. The same reading may be obtained by adding or subtracting, as the case may be, 45° to or from the index reading in the diagonal position. For instance, if the slot is in the position shown in fig. 3, 45° will be added.

In the diagonal position the vibrations which pass the lower nicol are resolved along the two directions of vibration in the section. If there were no relative retardation between the vibrations in these directions, they would on emergence recombine to form, once more, vibrations parallel to the direction of the vibration of the light when it left the lower nicol and would therefore be extinguished by the upper nicol. As a result, however, of the relative retardation this is no longer the case, and the various colours of the spectrum are transmitted in different degrees, so that the compound tints known as interference colours are obtained. These are dependent on the amount of the relative

retardation, which is usually approximately the same for all the colours of the spectrum.

Within certain limits every amount of relative retardation is distinguished by its own characteristic interference tint between crossed nicols, and these tints are practically the same for the majority of minerals, though the thickness required to give rise to a particular colour varies greatly for different minerals and according to the direction in which the same mineral may be cut. It is only in those minerals in which the relative retardation varies for different colours that unusual or *anomalous colours* are seen. These minerals are so few in number that the occurrence of their characteristic anomalous colours furnishes a ready means of distinguishing them. The indigo-blue seen in many thin sections of chlorite is a familiar example.

The normal interference colours commence with complete darkness at zero relative retardation and pass through grey, white, yellow, orange, and red, at the end of which the relative retardation reaches 550 micro-millimetres. These constitute the colours of the *first order*. Then follow purple, violet, blue, green, yellow and red up to a relative retardation of 1,100. These are the colours of the *second order*. Every addition of 550 micro-millimetres corresponds to another order with a similar succession of colours, which gradually become more complex till they are only represented by delicate shades of green and pink, and with a relative retardation of about 4,000 micro-millimetres they slowly pass into white light, the "white of the higher orders." The colours are said to be *lower* or *higher* according as they result from a less or greater amount of relative retardation.

If one nicol be rotated through a quarter turn so that the directions of vibration of the two nicols are *parallel*, the complementary colours are seen, which commence with white and pass through brown, red and blue to the yellowish green that marks the end of the first order at 550. The second order passes through yellow, red and blue to green again, and in the higher orders the colours gradually fade away through pinks and greens into white light exactly as with crossed nicols.

The amount of the relative retardation in a crystal section may often be roughly estimated directly from the interference colours between crossed and parallel nicols by comparison with

a table or lithographic plate of the colours with the corresponding relative retardations, but in determining colours so much depends on the idiosyncrasy of the observer and the character of the light that such estimates can only be relied on within very wide limits. In the smoky atmosphere of a London winter, for instance, the blue of the second order under crossed nicols appears, as Mr. T. Crook pointed out to me, to pass directly into greenish yellow without anything that could be definitely characterised as green intervening.

The *birefringence* may be defined as the *relative retardation in a unit of distance*. The relative retardation is, accordingly, equal to the product of the birefringence of the section and its thickness, the distance traversed. It can be shown that, if the same units are employed for both relative retardation and distance traversed, the birefringence is equal to the difference between the refractive indices of the two directions of vibration.

If then k be the relative retardation, l the thickness of the section, d the birefringence and μ and ν the refractive indices in the fast and slow directions, we have $k = l\,d = l\,(\nu - \mu)$.

In the case of a section of quartz 21 microns thick, cut parallel to the optic axis, the indices of refraction are 1·544 and 1·553 and the birefringence 0·009, which is the relative retardation in microns after traversing one micron. Accordingly $k = 21 \times 0{\cdot}009 = 0{\cdot}189$ of a micron.

If, however, the relative retardation be expressed, as usual, in micro-millimetres, it will, for the same thickness, be numerically a thousandfold greater. This value of the relative retardation may be denoted by K, and the corresponding value of the birefringence, that is to say the relative retardations in micro-millimetres after traversing one micron, by D, which will be, in the same manner, numerically a thousand times d, the value in homogeneous units. D may be referred to as the birefringence in millesims, where a millesim is a unit equal to 0·001. The equation then becomes $K = l\,D$. In the special case which has been taken, the birefringence is 9 millesims, so that $K = 21 \times 9 = 189$ micro-millimetres. This procedure has the advantage of avoiding small decimal amounts.

The birefringence varies according to the direction in which the section is cut in the crystal. The value given in text-books is the maximum birefringence, that found in sections cut parallel

to the optic axis in uniaxial crystals, and to the optic axial plane in biaxial crystals. The actual birefringence in a section may be anything between this and zero.

The maximum birefringence in millesims may be obtained from the value in homogeneous units found in text-books by moving the decimal point three places to the right.

The Quartz Wedge.—If the relative retardation is to be determined at the same time as the character of the directions of vibration, a quartz wedge or mica steps must be employed. The quartz wedge is cut in this country with its length parallel to the optic axis, which is the direction of vibration of the light propagated with the least velocity. The length is therefore slow (+) while the width is fast (−). As wedges are sometimes cut in different directions, the character of the length should be engraved on the glass as shown in fig. 3.

The wedge should be graduated so as to indicate the relative retardation at different points (see fig. 3). It should be inserted in focus (see p. 599), otherwise the colours will be blurred from overlapping and the graduation be invisible.

If the wedge be inserted in the slot between crossed nicols, when there is no birefringent mineral in the field or none which is not in the position of extinction, the normal succession of interference colours is seen commencing at the thin end of the wedge, where, however, the black and darker grey are usually missing on account of the difficulty of preserving the thin end from abrasion.

If, however, there is a birefringent mineral present in the diagonal position, so that the directions of vibration of the light traversing it are parallel and at right angles to the slot, and therefore parallel to those of light traversing the quartz wedge, the relative retardation of light traversing both the mineral and the wedge will be the combined effect of the relative retardation in each.

If the directions of the slow (+) and fast (−) vibrations respectively in the mineral are the same as in the quartz wedge, the colour seen at any point where the two are superposed will correspond to a relative retardation equal to the sum of the relative retardations of both. This may be referred to as the *additive* position. As the length of the quartz wedge is slow (+), the direction in the crystal which coincides with that of

the slot must evidently in this case also be slow (+). If on the other hand the slow direction of the wedge correspond with the fast direction in the crystal section and *vice versa*, the resulting relative retardation will be equal to the difference of relative retardations in the two, and they may be said to be in the *subtractive* position (fig. 3). In this case the direction in the crystal section parallel to the length of the wedge and therefore to the slot will be fast (−). If the relative retardation of the crystal section be within the limits of relative retardation shown by the wedge, there will, as the wedge is advanced through the slot in the subtractive position, be ultimately seen a black band traversing the crystal at right angles to the length of the wedge. This marks the point where the relative retardation in the wedge exactly neutralises that in the crystal section, being equal to it but opposite in character. The relative retardation shown in the graduation of the wedge at the point where the black band appears must therefore be that of the section also.

If the mineral gives rise to very high relative retardation and shows only pale pink and green tints or the white of the higher orders, except on the margin where bands of the lower-order colours are visible, the character of the section may most easily be determined by noticing how these bands move when the wedge is inserted. If they move inward from the margin, the mineral and the wedge are in the subtractive position; if outwards towards the margin, in the additive position. In such cases it is frequently desirable to employ an especially thick wedge with a comparatively large angle. It sometimes happens in the case of minerals with high birefringence that, even when the wedge is inserted in the subtractive position and the relative retardation at its thick end exceeds that of the mineral, no definite black band can be recognised, but when the wedge is inserted up to a certain point, irregular lines appear, which are too thin for the colours to be recognised, and when the wedge is pushed still farther in, they disappear. The mean of the values of the relative retardations of the quartz wedge at the points where these lines appear and disappear may be taken as that of the mineral under examination.

In all cases of difficulty in making this determination it is best to use strictly parallel light.

With strongly pleochroic minerals the black band does not

occur, as the excessive absorption of some or all colours in one direction prevents the recombination of the vibrations to form light vibrating parallel to the right and left cross wires. For the same reason the interference colours of such minerals are abnormal. As already stated, a similar result is obtained also where the birefringence—and therefore the relative retardation—varies considerably for different colours (see p. 606). In either case it is, however, generally possible to estimate with a fair amount of accuracy the central position from which the relative retardation with its corresponding colours increases in both directions.

Pleochroic sections may be referred to as *slow-dark* and *fast-dark* according as the character of the direction of maximum absorption is slow or fast. The latter case is comparatively rare, and when it occurs, as in aegyrine, riebeckite, arfvedsonite, apatite, and andalusite, is of considerable diagnostic value.

Similarly, where the colour varies considerably, crystal sections may be termed *fast-red* and *slow-green*, or as the case may be. Where the contrast is between red on the one hand and blue or green on the other, the fast vibrations are usually associated with the former.

In the double quartz wedge (fig. 4) which I described in the *Mineralogical Magazine* (vol. xiv. (1905), pp. 91–2) there are two wedges, one with the length slow (+) and the width fast (−), the other with these characters reversed. They have the same angle and the same birefringence, so that when cemented by Canada balsam side by side on a glass slip and inserted in the slot between crossed nicols the colours stretch across the two component wedges exactly as if they were one; but if a birefringent crystal section be in the field with its directions of vibration parallel and at right angles to the slot, one side will show additive effects and the other subtractive, so that the existence of a small relative retardation is easily recognised, and the amount of the relative retardation may be read off whichever direction of vibration in the crystal section is parallel to the slot. It may be noted that the colour in one component wedge opposite the black band in the other corresponds to a relative retardation exactly double that of the crystal section under examination.

All forms of quartz wedge should be carefully calibrated by

means of the dark and light bands which replace the colours in mono-chromatic light. The error may be thus determined within ten micro-millimetres.

Gypsum Plate.—If the relative retardation be very small it is difficult to detect or measure it by a quartz wedge on account of the imperfection of the thin edge of the latter. It is best investigated by means of a gypsum plate, parallel to the clino-pinakoidal cleavage, of such a thickness as to show the violet corresponding to a relative retardation of 575 micro-millimetres. A very small decrease in the relative retardation is sufficient to modify the colour considerably and cause it to pass into purple or red, while a slight increase changes it to indigo or blue.*

The gypsum plate is usually cut with its length parallel to the fast direction.† It may be inserted in either slot or in any other place in the course of the light between crossed nicols, but always in a diagonal direction. If a crystal section with low birefringence is now placed on the stage with its directions of vibration parallel and at right angles respectively to this direction, the colour of the plate will be seen to be modified so as to indicate an increase or decrease in the relative retardation. In the former case the vibrations in the crystal parallel to the slot will be fast, in the latter slow.‡

To determine the relative retardation of the crystal section, that of the combination is determined by means of the quartz wedge and the position of the black band on it. The stage is then rotated through an angle of 90° and the determination repeated. Half the sum will be the relative retardation of the

* Gypsum plates are, however, usually made to show the red of the first or second order, which is not so sensitive to variations in thickness and therefore easier to produce of a practically uniform tint.

† A circular plate mounted in wood is to be avoided, for if it becomes loose, as frequently happens, it loses its correct orientation. The plate should be marked so as to show the numerical amount of the relative retardation and the character of the length, as in fig. 5.

‡ In the case of small minerals with low relative retardation, which are rendered inconspicuous by the bright light to which the gypsum plate gives rise, it is better, if the construction of the microscope permits, to insert the plate in a direction making only a small angle with the cross wire. This diminishes the illumination due to the plate without affecting appreciably the illumination and colour of the mineral under examination (F. E. Wright, *Am. Journ. Sc.*, series IV., vol. xxxv., 1913, p. 66).

gypsum plate (which should agree with its previously ascertained value) and half the difference that of the crystal section. If the gypsum plate and quartz wedge are to be used together, the former should be inserted in the lower slot, leaving the upper for the latter; the upper nicol would then be necessarily placed above the eye-piece.

F. E. Wright has devised a useful combination of quartz wedge and gypsum plate,* and I have employed the same idea in the following manner (fig. 5). A quartz wedge is superposed on a gypsum plate showing the sensitive tint, both being constructed with the usual orientation (see above), so as to leave beyond the thin end of the wedge a square of gypsum which may be used as an ordinary gypsum plate. The quartz will show a black band where it exactly neutralises the gypsum, and the same succession of colours in opposite directions from this point, which is indicated by a line marked zero; but those on one side stop short a little before the colour of the plate is reached. Every hundred micro-millimetres of relative retardation on either side is shown by graduations. If the direction of the crystal section parallel to the slot be fast (−) the black band will move towards the thick end of the wedge, if slow (+), towards the thin end.

Mica Steps (fig. 6) consist of a succession of narrow cleavage plates of muscovite with their length cut parallel to the trace of the optic axial plane and therefore slow. Each strip should have a relative retardation of a hundred micro-millimetres. They are of different lengths, and when superposed form a succession of steps each large enough to cover the whole cone of light in the lower slot, where they are usually employed, though they are equally useful in the focus of the eye-piece, if the upper nicol be placed above them. In either case they show a discontinuous series of colours corresponding to differences of one hundred micro-millimetres. If they are inserted over a crystal section it is easy to see whether the two show additive or subtractive relations. In the former case the stage should be rotated till the fast direction of the crystal section is parallel to the slot. It may then happen that the crystal section is exactly neutralised by one of the steps and must therefore have the same relative

* *Journal of Geology*, vol. x., 1902, pp. 33–35. See also *Min. Petr. Mitt.* (*Tschermak*), vol. xx., 1901, pp. 275–6.

retardation. Usually, however, while one of the steps fails to neutralise the section, the next higher will more than do so, and neither will be completely dark. If they are equally bright, the relative retardation of the section must be midway between those of the two steps. If one be darker than the other the relative retardation will be proportionately nearer to that of the darker step. In this way it will be possible to estimate the relative retardation to within twenty or thirty micro-millimetres.

If a further approximation be desired it may be obtained by employing additional smaller mica steps divided into four portions with twenty, forty, sixty and eighty micro-millimetres relative retardation respectively. If the larger mica steps are inserted in the lower slot, the smaller can be placed in the upper. In this way it is possible to determine relative retardation to within ten micro-millimetres and make estimations to within half that amount.

Mica steps are one of the many useful pieces of apparatus devised by Fedorov, but the description given above differs from his directions in some details, having reference chiefly to the amount of the relative retardation represented by each step.

Mica steps may be calibrated by reference to a quartz wedge the errors of which have already been determined.

In order to obtain the birefringence of the section from the relative retardation it is necessary to determine the thickness. As this will usually involve the movement of the rock-slice it is better postponed till after the "directions-image" has been examined. For the same reason the determination of the refractive index should also be deferred to a later stage.

The Directions-Image.

It is frequently desirable to examine simultaneously the optical properties of a number of different directions in a mineral, so that a comprehensive idea of its optical characters may be obtained. For this purpose the microscope is, in the manner which will be described, converted into an optical instrument in which every point in the image corresponds not to a point in the object under examination, but to a direction along which light traverses that object in parallel paths. Such an instrument may be conveniently described as a *hodoscope* or path viewer, a

term which is to be preferred to the word "konoscope" employed by some authors.

If a microscope, from which the eye-piece had been removed, were directed vertically upwards towards a cloudless sky at night, the images of all the brighter stars within a certain distance of the zenith, dependent on the angular aperture of the objective, would be seen on the principal focal surface of the objective—that is to say, its focal surface for light from an infinite distance. Each of these images would be formed of light which had been travelling by parallel paths, or in other words in the same direction, which would of course be different for different stars. By day the whole field would be illuminated and every point in it would represent light which had reached the objective from a particular direction. If a mineral section were now interposed close to the objective, every illuminated point on the focal surface would represent a direction in the crystal section, which would be determined by the construction of the objective, the position of the point relatively to it and the refraction at the surface of the section. The image thus obtained representing different directions in a mineral may be described as the *directions-image*, as opposed to the *object-image* in which the microscope is focused on the object itself.

As it is inconvenient to direct the microscope to the sky, the different directions in the mineral section are illuminated by placing below the stage and above the mirror of the microscope a *condenser* consisting of a convergent lens or system of lenses. For this reason the directions-image is frequently referred to as the "image in convergent light," an altogether misleading expression, since convergent light is habitually employed with close objectives, when the microscope is focused on the object itself, or in other words when the object-image is under examination. In observing the directions-image it is usually desirable to employ wide-angled objectives, so as to include as many directions as possible, and the angular aperture of the condenser must be at least as great.

The directions-image of small crystals, grains and fragments may be examined in like manner, though the results are modified by the varying effects of refraction at different points, unless the medium in which the object is immersed has approximately the same index of refraction as the object itself. The inter-

ference colours are also affected by the variations in the thickness traversed, even by light moving in parallel directions.

The Bertrand Lens.—As the directions-image formed by the objective is small and somewhat inaccessible, it is usual to employ a *Bertrand lens*, a convex lens, which is placed, when required, in the tube, and forms a secondary directions-image in the focus of the eye-piece. The Bertrand lens is, as a rule, inserted a short distance above the objective, but is sometimes placed higher up, and then occupies only the centre of the tube, so that a large portion of the object-image may, if desired, be left visible. If this be done, the observer can, without losing sight of the directions-image satisfy himself from time to time as to the point on which the microscope is directed and, if desired, change from one portion of the crystal section to another.

The Bertrand lens should be capable of being focused by a sliding movement along the axis of the microscope, and it is important that this movement should have sufficient range for the purpose, which is not always the case.

The Becke Lens.—Instead of inserting the Bertrand lens in the tube, it is possible to obtain the same result more conveniently by placing the Becke lens above the eye-piece. This is a convex lens or system of lenses, similar to a Ramsden eye-piece, which magnifies the directions-image formed in the Ramsden circle of the eye-piece. It should have a focusing movement.

Isolation of the Directions-Image of a Mineral.—If the mineral under examination is not alone in the field, it is desirable to isolate it so that the effects of different minerals may not be blended and thus interfere with one another.

This object may sometimes be attained by using a closer objective and thus diminishing the extent of the rock-slice or glass slip included in the field.

A more generally available method, however, is to cut off all light except that reaching the mineral under examination. For this purpose a diaphragm may be placed a little distance below the condenser, which is adjusted so that the image of the aperture in the diaphragm is focused simultaneously with the object.

In some microscopes the iris diaphragm, attached to the condenser for carrying out the Becke method of determining the relative refractive indices of minerals in thin sections (p. 626),

may be employed.* In that case all that is necessary is to focus the microscope on the object, and after nearly closing the diaphragm lower the condenser till the aperture in the diaphragm appears in focus. The glass slip is then adjusted, if necessary, so that the mineral to be observed is in the centre of the field and the diaphragm opened or closed till the maximum area of that mineral, but no portion of any other, is illuminated.† It is scarcely necessary to add that the greatest care must be taken to see that the nose-piece is exactly centred so that the object remains in the illuminated area during the rotation of the stage. The Bertrand or Becke lens is now placed in position and the directions-image can be studied.

The same result can be obtained by placing a diaphragm at any point above the object where a *real* object-image is formed, provided of course that it is not affected by the conversion of the microscope into a hodoscope. One of the following methods, preferably the second, may be employed :

1. If the eye-piece be removed, an object-image can be formed exactly at the upper end of the microscope tube by operating the coarse or fine adjustment. The mineral selected for examination is then brought into the centre of the field and a cap with a central perforation, not larger than the image of the mineral, is placed on the end of the tube. If the eye be now placed close to the aperture, the directions-image will be seen low down in the tube in the position already described, illuminated only by light which has traversed the mineral.

2. The eye-piece may be retained and the mineral to be studied isolated by means of a diaphragm in the focus of the eye-piece. The Becke lens is then placed in position and the directions-image of the mineral, unmixed with other light, is seen.

3. If the Bertrand lens be employed, an object-image is formed above it and below the eye-piece, and can be seen if the eye-piece be removed. A diaphragm may be inserted here, but the low magnification of the image is a drawback. A diaphragm is frequently placed just below the Bertrand lens.

* In other instruments the iris diaphragm is so close to the condenser that the latter cannot be lowered sufficiently to bring it into focus. Another diaphragm must then be provided.

† Light traversing glass or other isotropic substances will not, however, affect the result, if the nicols be crossed.

In that case to make the object-image coincide with the diaphragm, a lens, or a combination of a lens with the eye-piece, is focused on the position of the diaphragm and the tube raised till the object is seen in focus. The angle of the cone illuminated by the condenser is, however, diminished by the elevation of the objective.

I now proceed to describe some of the phenomena seen in the directions-image, especially those which may be easily observed in minerals in thin sections and afford important information with regard to their optical characters, as well as the directions in which they have been cut.

Interference Colours in the Directions-Image. — When the directions-image is examined between crossed nicols it shows in the centre of the field the same interference colour as that seen in the object-image. From the centre outwards this passes into other colours corresponding to different amounts of relative retardation which may be greater or less than that in the centre. The colours move with the stage as it rotates without suffering any change of configuration.

Isogyres.—At the same time the field is traversed by dark bands or brushes, which constitute the *isogyre.** As the rotation proceeds, this, as a rule, changes both its position and its shape and from time to time leaves the field altogether.

When the stage is in the position corresponding to extinction in the object-image, in other words when the vibrations in the plane of the crystal section are parallel to the cross wires, the isogyre passes through the centre of the field and is known as a *central isogyre* (figs. 7, 8, 13, 16–21).

The visible portion of the isogyre consists in the majority of cases of a single dark band, which usually expands towards the margin of the field to form a less definite brush. This moves four times across the field as the stage rotates, being usually lost to view in the intervals.

In other cases the isogyre consists of two dark bands which either meet in a cross or form the two branches of an hyperbola.

The following special types of central isogyres formed of a single band may be distinguished.

A symmetrical isogyre is straight and parallel to one of the

* F. Becke, *Min. Petr. Mitt.* (*Tschermak*), vol. xxiv., 1905, pp. 1–34, and *Min. Mag.* vol. xiv., 1907, pp. 276–80, and J. W. Evans, *ib.* pp. 230–3.

cross wires and therefore to one of the directions of vibration in the section (figs. 7, 8 and 17). A section showing a symmetrical isogyre is itself said to be symmetrical.

A symmetrical section is always cut at right angles to a plane of optical symmetry, of which the central isogyre is the trace.

Every section of a uniaxial mineral is cut at right angles to a plane of optical symmetry, while this is only exceptionally the case with sections of biaxial crystals. If, therefore, every section of a mineral in a rock section shows a symmetrical isogyre, we may safely assume that the mineral is uniaxial.

As a general rule in biaxial crystals a central isogyre is curved and oblique to the cross wires (figs. 16, 19).

A *pseudosymmetric isogyre* is straight, but is parallel not to one of the cross wires, but to the line bisecting the angle between them (fig. 18).

A pseudosymmetric section is only met with in crystals whose optic axial angle is 90° and the normal of such a section lies in one of the planes containing the optic normal and one of the optic axes of the crystal.

If an isogyre is formed of two bars, but only one of these passes through the centre of the field, the nature of the isogyre and of the section is determined by the portion of the isogyre which passes through the centre.

If the two bars meet at right angles in the centre and form a cross, they are both straight and parallel to the cross wires and therefore symmetrical. The section must accordingly have been cut at right angles to two planes of optical symmetry and to the line of optical symmetry in which they meet. In a biaxial crystal this line is either a bisectrix or the optic normal. In the latter case, the cross is somewhat indistinct and in crystals with an optic axial angle approaching a right angle it becomes unrecognisable. If a section of a uniaxial crystal show a central cross, it is either cut at right angles to the optic axis, and therefore to an infinite number of planes of optical symmetry, or it is parallel to the optic axis. In the latter case, again, the cross is indistinct.

The Movements of Isogyres.—The movements of a symmetrical isogyre, when the stage is rotated alternately in opposite directions, are symmetrical to the cross wire to which it is parallel, while those of a pseudosymmetric isogyre are symmetrical in the same

way to the diagonal to which it is parallel. If the movements are unsymmetrical, the isogyre must be so likewise.

If, when the stage is rotated, one of the ends of an isogyre at the boundary of the field moves round the circumference in the same cyclical direction as that in which the stage is rotated, that end is said to be *proximal*. If it moves round in the opposite direction or is stationary, it is *distal*. The terms homodrom and antidrom are used by Becke, but they are misleading, if a microscope with rotating nicols be employed, and proximal and distal are accordingly more suited for general use. The manner in which they are applied is illustrated in figs. 7, 9–11 and 16–18.

An isogyre consisting of a single band has usually one end proximal and the other distal. A proximal end is directed towards the nearest optic axis, or, if it be practically equidistant from the two optic axes, to the nearest bisectrix.

An isogyre consisting of two bars intersecting in a cross has in biaxial crystals (fig. 13) two proximal ends opposite to each other and two distal ends. If the centre of the cross represents a bisectrix, the proximal ends are directed towards the optic axes and the bar to which they belong marks the trace of the optic axial plane. The distal ends lie in the direction of the optic normal. If the section is, on the other hand, cut at right angles to the optic normal, the proximal ends point to the acute bisectrix and the distal towards the obtuse bisectrix.

On rotation of the stage the cross breaks up into two hyperbolic branches, each with one proximal and one distal end. These move away from the centre and may pass entirely out of the field.

In sections of uniaxial crystals cut at right angles to the optic axis (fig. 21) the cross does not break up on the stage being rotated, and the ends are stationary and therefore distal. The phenomena in sections parallel to the optic axis are similar to those in sections at right angles to the optic normal in biaxial crystals. The proximal ends are directed towards the optic axis, while the bar with distal ends lies in the plane of optical symmetry at right angles to the optic axis.

If the distal end of an isogyre move more rapidly than the proximal end, the movement may be compared to that of a pendulum. This happens when the proximal end is directed towards an optic axis. If the section is symmetrical, either

it is at right angles to the optic axial plane of a biaxial crystal, or it is a section of a uniaxial crystal, which makes a very large angle with the basal plane.

If both ends move at nearly the same rate, the isogyre passes straight across the field, maintaining approximately its rectilinear form and keeping parallel to one of the cross wires (fig. 11). This is the case in sections of uniaxial crystals which make only a moderate angle with the basal plane. It is not the only movement occurring in isogyres of uniaxial minerals, as is commonly supposed to be the case.

Longitudinal and Transverse Directions.—A direction of vibration (or extinction) is said to be *longitudinal*, when it is parallel to the central isogyre where it passes through the centre, or when it makes an angle of less than 45° with it. The *transverse* direction of vibration is that at right angles to the longitudinal direction. If a central isogyre is *diagonal*, that is to say if it bisects the angle between the cross wires, the directions of vibration are neither longitudinal nor transverse.

The ends of a longitudinal direction nearest to the proximal and distal ends of the isogyre may themselves be described as proximal and distal respectively.

In a central cross which breaks up into hyperbolic branches when the stage is rotated, the horizontal or vertical bar with two proximal ends marks the longitudinal direction, and in the diagonal position becomes the axis of the hyperbola, if one be visible (figs. 13 and 14).

If there be a central cross which does not break up, the section is, as already stated, cut at right angles to the optic axis of a uniaxial crystal, and all directions are longitudinal (fig. 21).

The Character of Isogyres and Sections.—The character (sign) of a central isogyre is that of the longitudinal direction (see p. 605), and the same character is attributed to the section itself. A diagonal isogyre and its section are said to be *neutral*, for they can be neither fast nor slow, since there is no distinction between longitudinal and transverse directions.

The determination of the character of sections in a rock-slice enables us to form a conclusion as to the character of the mineral as a whole.

In a uniaxial crystal the character of all sections is the same as the character of the mineral, which is that of its optic axis.

In a biaxial crystal the character of the greater number of sections is the same as that of the mineral, which is that of its acute bisectrix. The smaller this angle the more frequently the character of sections coincides with that of the mineral.

A section with pendulum movement and higher relative retardation than most other sections of the same mineral with the same thickness will always have the same character as the mineral itself.

A pseudosymmetric section indicates that the crystal is neutral, in other words, that its optic axial angle is 90°, but only certain sections of a neutral crystal are pseudosymmetric, and other neutral sections do not necessarily belong to a neutral crystal.

The character of the longitudinal direction is best ascertained in the object-image in the manner already described, but as will be seen it may also be determined from the directions-image itself.

To identify the longitudinal direction and its proximal and distal ends in the sketch of the object-image, the stage should be rotated till in the directions-image the central isogyre is seen to coincide or make an angle of less than 45° with the right and left cross-wire and have its proximal end to the right. This may be termed the index position of the isogyre, for the index reading will then give the position of the proximal end of the longitudinal direction of vibration.

When the isogyre is in the index-position, the character of the longitudinal direction may be determined by inserting a gypsum plate in the slot (figs. 8 and 16). If this be done the isogyre itself will assume the colour characteristic of the plate, but will be bordered by higher colours on one side and lower colours on the other. If the colours are lower on the same side as the proximal end of the slot, the character of the longitudinal direction and therefore of the isogyre and section will be the same as that of the direction of the gypsum plate parallel to the slot. By the proximal end of the slot is meant of course that nearest the proximal end of the isogyre and of the longitudinal direction of vibration. If the procedure already described has been followed, this will be the right-hand end. If the colours are higher on the same side as the proximal end of the slot, the character of the section will be opposite to that of the direction in the gypsum plate parallel to the slot.

For instance, if the slot be in the position indicated in figs. 8

and 16, and the colours be lower on the margin of the isogyre farther from the observer as in those figures, the character of the section will be the same as that of the plate parallel to the slot.

These methods apply both to uniaxial and biaxial crystals. The inferences that can be drawn from the characters of one or more sections with reference to that of the mineral have already been described (pp. 620, 621).

Sections Perpendicular to an Optic Axis.—These may be recognised in the object-image by the darkness in all positions * in a uniaxial mineral, and in a biaxial mineral by a feeble illumination which does not vary when the stage is rotated. They show no relative retardation and are therefore neutral.

If a gypsum plate be inserted in the slot over the directions-image of such a section of a uniaxial crystal, the black cross in the directions-image will be represented by a cross of the colour characteristic of the plate; and if the mineral be of the same character as the direction in the plate parallel to the slot, the quadrants through which the slot passes will show higher colours, and the other quadrants lower colours, while if it be of the opposite character, the contrary will be the case. If a quartz wedge or mica ladder possessing the same character as the mineral be pushed progressively in, the rings of colour in the former quadrants will contract, and in the latter will expand, and if it possess the opposite character, the same phenomena will occur in the alternate quadrants.

In biaxial crystals cut at right angles to an optic axis, the isogyre always passes through the centre, and has two distal ends. In certain positions it is straight and parallel to a cross wire and lies in the optic axial plane. If then the stage is rotated through 45° towards the slot, the isogyre becomes a branch of an hyperbola with its axis parallel to the slot (fig. 19). If a gypsum plate be now inserted, the hyperbolic isogyre will show the interference colour of the plate, and at the same time, if the crystal have the same character as the direction in the plate parallel to the slot, the concave margin will exhibit higher colours

* Isotropic crystals will also be dark in all positions in the object-image, but the directions-image will show a uniformly dark field instead of a cross, unless, as sometimes happens, the glass of the objective is in a state of strain, when a feeble uniaxial cross may be visible.

(fig. 19), while the convex margin will exhibit lower colours. If the crystal have the opposite character, the reverse will be the case. The amount of the curvature of the isogyre in this position gives some idea of the magnitude of the acute optic axial angle. If the isogyre be straight, the angle will be 90° (fig. 18), while if it forms a right angle coinciding with two arms of the cross wires, it is 0°. In this case the other branch of the hyperbola coalesces with it, forming the cross characteristic of a uniaxial crystal (fig. 21).

A very rough approximation to the optic axial angle, which may be employed for determinative purposes, may be obtained by taking the angular distance θ round the circumference of the field between the darkest point in one end of a branch of the hyperbola and the nearest cross wire, and doubling it (fig. 19). The result is usually too high, especially for medium angles, in which the error may amount to 10°. F. Becke has shown how a much more accurate result may be obtained,* and a still more rigorous procedure is described by F. E. Wright.†

These methods may be applied even when the section is not exactly at right angles to the optic axis, if the point of emergence of the latter appears in the directions-image (fig. 20). Such sections may be recognised in the object-image by the comparatively low relative retardation.

Sections showing a Black Cross which breaks up on Rotation of the Stage.—Unless the section be at right angles to an acute bisectrix, the character of the longitudinal direction of vibration (see p. 620) will be that of the crystal, and this will always be the case if the section shows high relative retardation compared with most other sections of the same mineral with the same thickness. The black crosses seen in sections of uniaxial crystals parallel to the optic axis and of biaxial crystals at right angles to the optic normal are distinguished by the rapidity with which they break up and leave the field when the stage is rotated. Where the optic axial angle is small, sections at right angles to the obtuse bisectrix resemble those at right angles to the optic normal.

* *Min. Petr. Mitt.* (*Tschermak*), vol. xxiv., 1905, pp. 35–44; *Min. Mag.*, vol. xiv., 1907, p. 280.

† *American Journal of Science*, Series IV., vol. xxiv., 1907, pp. 332–341. In the same paper other methods are discussed.

In neutral crystals and in those in which the optic axial angle differs but slightly from a right angle, the optic normal, as we have seen, shows no cross, and those seen in sections at right angles to the two bisectrics are indistinguishable.

If the optic axial angle is so small that both optic axes are visible in the same section, the methods already described for the case where one optic axis is present may be employed (fig 14).

Variations of Relative Retardation in a Directions-Image.—There is usually a decrease in the relative retardation indicated by the interference colours towards the proximal margin or margins of the field, and this may be utilised to determine the position of the longitudinal direction and its proximal end. For this purpose the stage is rotated though 45° from the position of extinction. Unless an optic axis is visible, the isogyre will then have passed out of the field and the region of lowest interference colours will mark the position of the proximal end of the longitudinal direction (fig. 12). If the section be at right angles to a line of optical symmetry, there will be two opposite regions of lowest relative retardation (fig. 15), and the line joining them will be the longitudinal direction. This method is frequently useful where the isogyre is indistinct.*

In doubtful cases the gypsum plate may be inserted, and then the region that approximates most closely to the colour of the plate will have the lowest birefringence and indicate the proximal end and longitudinal direction. If this be at a point within 45° of the slot and the colour be higher than that of the plate, the character of the section will be the same as the character of the plate. If it be more than 45° from the slot, or the colour be lower, the character will be opposite to that of the plate. If both these conditions hold good, it will be the same as that of the plate. In neutral sections the lowest colour will be about 45° from the slot.

If the optic axis be in the field, the line joining it to the centre will be the longitudinal direction. Some portions of the field will then have a higher and others a lower colour than the plate, and the colour in the centre of the field will determine the character of the section, unless of course the optic axis is in the centre of the field, when the character will be neutral (p. 622).

Theodolite Stage.—In recent years Fedorov has introduced

* J. W. Evans, *Min. Mag.*, vol. xiv., 1907, pp. 233–4.

the "universal" or *theodolite stage* by means of which the properties of light vibrating in different directions may be studied in parallel light in the object-image of a single section by rotating the latter on two or more axes. The subject is, however, too extensive to be considered on this occasion.

Other Determinations.

The Thickness of the Rock-slice.—The only practicable method of determining the thickness of an ordinary rock-slice is to select a known mineral whose maximum birefringence is practically constant and not too low, such for instance as quartz, orthoclase, olivine, calcite and (for approximate results) an acid or intermediate plagioclase. Search is then made for the section of this mineral which shows the highest relative retardation, and it may be assumed that its birefringence has as nearly as possible the maximum value. Suppose the mineral to be quartz, with a birefringence of 9 millesims (0·009), and the greatest relative retardation observed to be 315 micro-millimetres. Then the thickness of the section will be $315 \div 9 = 35$ microns.

The thickness should be determined, if possible, at several points so as to obtain an idea of its variation in different parts of the rock-slice. If the thickness of the rock-slice is not uniform, that of the crystal section must be estimated from its position in the slice as nearly as possible. The thickness should be stated on the sketch, and indicated by the depth of the scale (fig. 1). If the thickness is not uniform, the amount of variation may be indicated in the same way.

Determination of the Birefringence.—Knowing the thickness of a crystal section and its relative retardation, we are able to determine its birefringence by dividing the latter by the former. For instance, if the section has a relative retardation of 340 micro-millimetres and a thickness of 28 microns, the birefringence will amount to $340 \div 28 = 12$ millesims or 0·012.

A number of different crystals of the same mineral are dealt with in this matter, and it may be assumed that the maximum birefringence thus obtained falls but little short of the maximum birefringence of the mineral.

The Refractive Index.—A knowledge of the index of refraction of a mineral is a valuable means of recognition. In the case

of a thin section in a rock-slice only relative determinations of refractive indices are possible in an ordinary petrological microscope, comparison being made either with the Canada balsam or other medium in which the rock-slice is immersed, or with an adjoining crystal.

For the Becke method a high power is employed, and the cone of illumination is narrowed. This may be effected by removing or lowering the condenser and inserting a cardboard slip with a hole one or two millimetres in diameter twenty or thirty millimetres below the stage.* A slit of the same diameter parallel to the boundary of the section may be substituted. This is equally effective and does not cut down the light to the same extent. The boundary surface between the section and the medium or adjoining crystal must be at right angles to the surface of the rock-slice. This can be verified by observing if it remains constant in position when the focus is varied.

If now there be an appreciable difference between the refractive indices on opposite sides of the boundary, one margin of the boundary will usually be seen to be lighter than the field in general and the other darker. If the objective be focused on a point in the neighbourhood of the upper surface of the section, the light margin of the boundary will be on the side with the higher refractive index and the dark margin on that with the lower refractive index. If the focus be gradually lowered, these bands will be reversed in position.

In this way it is possible to determine whether the refractive index of a crystal mounted in Canada balsam is higher or lower than that of this substance. If, however, the crystal is uncovered, and its margin free from balsam, it may be immersed in a succession of films of liquid of different refractive indices and its refractive index thus determined between comparatively narrow limits.

If the crystal section be birefringent the observation should be made with the lower nicol in position, and first one and then the other direction of vibration in the crystal should be brought into parallelism with the direction of vibration in the lower nicol. In this way the indices of refraction parallel to both directions of vibration may be determined.

* An iris diaphragm is often provided, and is more convenient.

If the directions of vibration of adjoining crystal sections are parallel, exact comparison of the refractive indices corresponding to each pair of parallel directions may be carried out in the same manner. In other cases *parallel* nicols should be employed and the stage rotated till their direction of vibration bisects the angle between the directions of the pairs of vibration the refractive indices of which are to be compared. In all cases a comparison of the *mean* refractive indices may be made by dispensing with the use of a nicol.

If a crystal or grain be immersed in Canada balsam or other medium, such as a highly refracting liquid, or a larger crystal, the relation between its refractive index and that of the surrounding material may be determined by the Schröder van der Kolk or "finger" method. A condenser is employed and placed *close* below the object, or the effects will be reversed. One side of the illumination is then shaded, usually by the finger placed below the lower nicol. If a shadow appear on the same side of the object as the finger is placed, the refractive index of the object is higher than that of the medium. If it appear on the opposite side, the refractive index is lower than that of the medium. By means of a nicol the two directions of vibration can be separately examined in the manner already explained.

With monochromatic light this method gives good results. It is usual to provide a series of liquids, the refractive indices of which differ by small amounts, starting from about 1·47 and extending up to 1·76, afforded by methylene iodide, or 1·83 by a solution of sulphur in methylene iodide, which is, however, not so satisfactory. If an exact determination be required, a mixture of two liquids is prepared, which has as nearly as possible the same refractive index as the mineral, and the index of refractive of this mixture is determined by the Abbé refractometer. It is important to remember that the refractive indices of liquids change considerably with the temperature.

If white light be employed, the phenomena are complicated by the fact that the dispersion of the colours in liquids is usually much greater than with solids of the same refractive index, and a series of colour phenomena may result, which complicates the observation. In the case of minerals with decidedly higher or lower refractive indices than the medium there is no difficulty;

but if the mineral has about the same refractive index for blue light as the medium, but a higher refractive index for red light, only the red light will be obscured on the same side as the finger, so that the shadow will have a bluish tinge. When all the refractive indices of the mineral are included between the extreme indices of the medium, there will be a bluish colour on the finger side and a yellowish-red one on the opposite side; and when the red refractive indices are the same but the blue refractive index of the medium is greater, there will be a red shade on the far side. The colours obtained with particular liquids are sometimes very characteristic of minerals, and may thus be employed for their identification.

All the particulars obtained in the investigation of the mineral sections should be embodied in the sketch as shown in fig. 1.

The following is a brief abstract of the procedure in the detailed examination of the optical characters of a mineral.

A. Examination of the object-image.

1. With stage in the zero position, sketch the mineral and indicate the positions of 0°, 90°, 180° and 270° by short lines directed inwards from the circumference (p. 601).

2. Determine the positions of edges, cleavages and other rectilinear directions in the mineral and indicate them by discontinuous lines through the centre, each distinguished by its two index readings (p. 601).

3. Determine the extinctions or directions of vibration and show them as continuous lines through the centre with index readings (pp. 601–604).

4. Note the absorption colours and other phenomena shown by light vibrating in these directions (p. 604).

5. Determine the character of the directions of vibration and the amount of relative retardation (pp. 604–613).

B. Examination of the directions-image.

6. Determine the longitudinal direction and its proximal end, and deduce the character of the section, noting at the same time the nature of the movement of the isogyre and any special features in the directions-image (pp. 617–624).

All the above observations should be made, if possible, without moving the object. If any movement be necessary, it should be made without changing the orientation. This is best effected by the use of a mechanical stage.

C. Observations extending to other crystals of the same mineral and other minerals.

7. Determine the thickness of the rock-slice and calculate the birefringence of the mineral under examination (p. 625).

8. By determining the character of other sections of the same mineral or of those showing special features, determine that of the mineral itself (pp. 620–624).

9. Determine the refractive index of the mineral as far as circumstances permit (pp. 625–628).

Explanations of Figures.

Fig. 1. Crystal section in the position in which it is originally drawn with index-reading zero. Most of the details shown are subsequently added. The directions of extinction are represented by thick lines, crystallographic directions by interrupted lines, and the position of the cross wires only by short thick lines.

,, 2. Crystal section with the long edge and cleavage parallel to the right and left cross wire. The index-reading 83° is shown on the right end. The directions which originally coincided with the cross wires are shown by short thick lines. The actual cross wires are represented here and in fig. 3 by thin continuous lines.

,, 3. Crystal section with the fast (−) direction of vibration parallel to the slot. The quartz wedge is inserted, and shows a black band where it exactly neutralises the crystal. The smaller figures in the scale on the wedge indicate hundreds, the larger thousands of micro-millimetres of relative retardation.

,, 4. Double quartz wedge.

,, 5. Combination gypsum plate and quartz wedge.

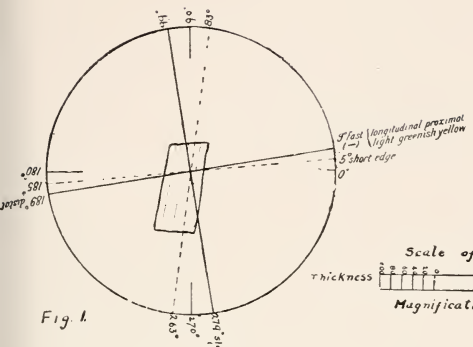
,, 6. Mica steps.

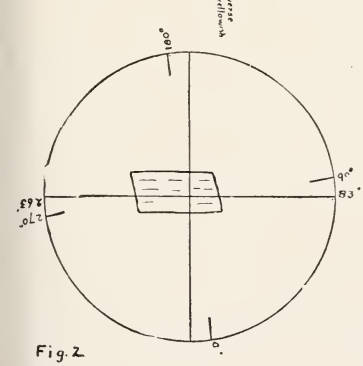
,, 7. Straight central isogyre showing only one branch. The inner arrows give the directions in which the ends of the isogyres would move if the stage were rotated in the direction of the outer arrows.

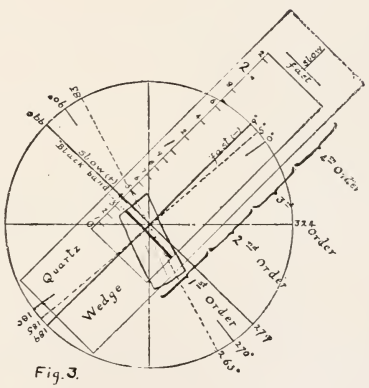
,, 8. The same with gypsum plate inserted. The lower colours on the farther side of the isogyre show that the character of the section is fast (−).

Fig. 9. Pendulum movement obtained by rotation from fig. 7.
,, 10. Fan movement from fig. 7.
,, 11. Parallel movement from fig. 7.
,, 12. Fig. 7 rotated through 45°. The lower colour in the north-east indicates the longitudinal direction and its proximal end.
,, 13. Straight central isogyre of two branches meeting in a black cross in a biaxial crystal.
,, 14. The same rotated through 45° with the vertices of the isogyre still visible in the field. The gypsum plate is inserted, and the lower colours on the concave sides of the curves show the crystal to be slow (+).
,, 15. Fig. 13 rotated through 45° in a case in which the vertices of the isogyre have disappeared. The lower colours indicate the longitudinal direction.
,, 16. Curved central isogyre with gypsum plate. The lower colours on the farther side of the isogyre indicate that the section is fast (−).
,, 17. Section at right angles to one of the optic axes of a biaxial mineral. The optic axial plane lies east and west.
,, 18. The same rotated through 45° when the crystal is neutral.
,, 19. The same when the crystal is not neutral. The gypsum plate is inserted, and the higher colours on the concave side of the curve show that the crystal is fast (−).
,, 20. The same with smaller optic axial angle showing two branches of the isogyre.
,, 21. Section at right angles to the optic axis of a uniaxial crystal—that is to say, one in which the acute optic axial angle is zero. The higher colours in the angles traversed by the slot and plate show that the crystal is fast (−).

The directions of the arrows in figures showing isogyres indicate the relations between the angular directions of the movements of the ends of the isogyre and that of the rotation of the stage, and their lengths the relative angular velocities.







DETERMINATION OF MINERALS.

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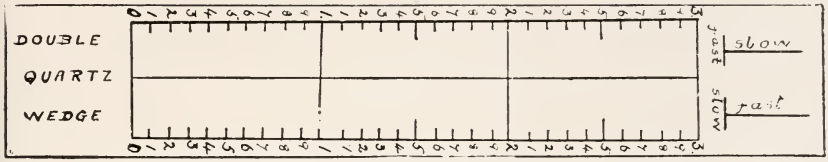
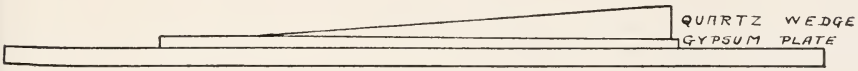


Fig. 4.



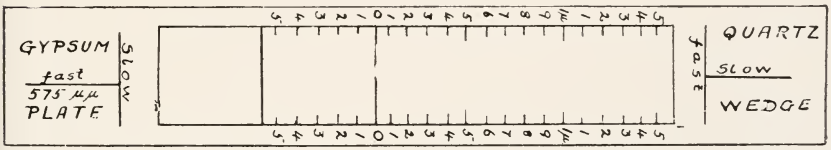
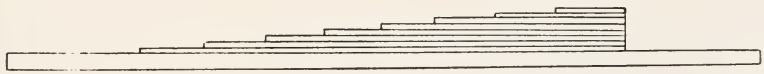


Fig. 5.



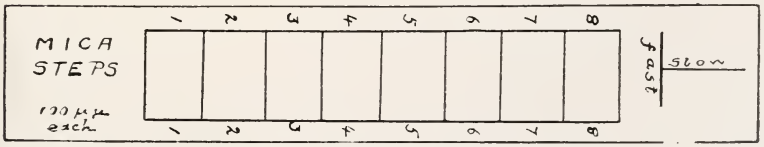


Fig. 6.

Determination of Minerals.

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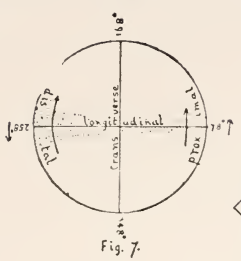

Fig. 7.

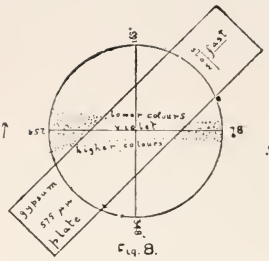

Fig. 8.

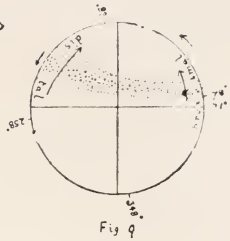

Fig. 9.

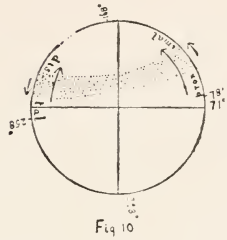

Fig. 10.

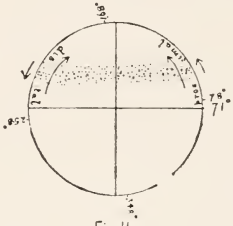

Fig. 11.

Fig. 12.

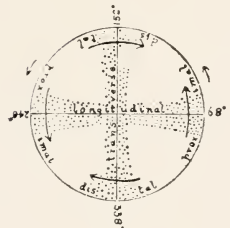

Fig. 13.

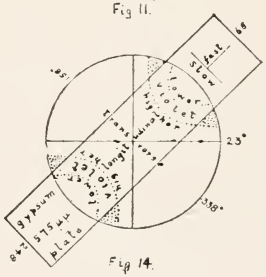

Fig. 14.

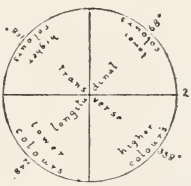

Fig. 15.

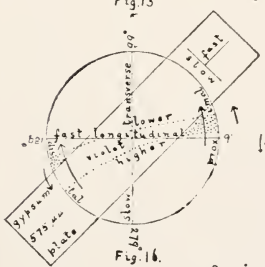

Fig. 16.

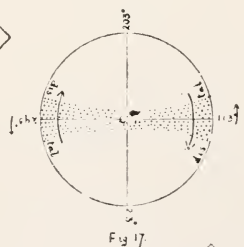

Fig. 17.

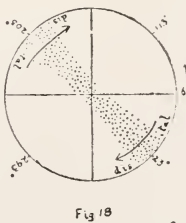

Fig. 18.

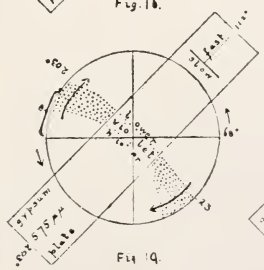

Fig. 19.

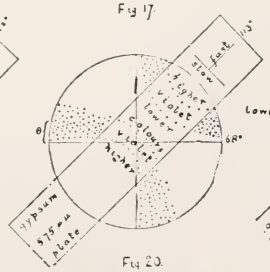

Fig. 20.

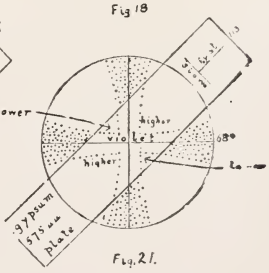

Fig. 21.

DETERMINATION OF MINERALS.

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ON FIVE NEW SPECIES OF THE GENUS *HABROTROCHA*.

By David Bryce.

(*Read October 26th*, 1915.)

Plates 38 and 39.

In the following paper I describe five new species of pellet-making Rotifera, which are to be added to the already important genus *Habrotrocha*. The first two, *H. insignis* and *H. sylvestris*, may be said to belong to the central group of the genus, being closely related to *H. angusticollis* (Murray), which has been designated as type species by Woodcock.* The characteristics of this central group consist of a relatively long and slender head and neck, a middle body distinctly stouter, and an exceedingly short foot, together with rather narrow trochal disks borne on somewhat high pedicels usually adnate. *H. insignis* has other more special characteristics, one of which has not been seen in any other Bdelloid. The upper lip, when closely examined, is found to have a curious stiffening, apparently that it may better support the slender pedicels under the strain of the lashing cilia above. This stiffening is not very obvious, but once observed is readily recognised and can be detected even when the corona is retracted within the mouth.

A second interesting structure is the looping of the gullet in a certain position of the body. A similar structure has been already noted by Zelinka for *Habrotrocha Leitgebii*, and it is also present in two of the other new species, viz. *H. sylvestris* and *H. flava*. The looping of the gullet is one of several structural modifications that are distinctly connected in their origin with the attitude assumed by the rotifer when it is feeding. There are some Bdelloids of the family of the Philodinidae which feed without attempting to extend themselves, but others extend themselves habitually to the utmost, without doubt in order to

* Woodcock, *Int. Cat. Sci. Lit.*, vol. x., 1911. *Zoology*, vi. p. 45.

gather food from the increased area thereby brought within the influence of the vortices set up by the cilia of the trochal disks. This habit of extension for the purpose of increasing the food supply reacts in two different ways upon the structure of the body. One of these is very apparent in such species as *Rotifer vulgaris* and its nearer relatives, where the foot and the rump segments have become so elongated that they constitute quite a large proportion of the whole length of the animal.

In the central section of the Habrotrochae the head and neck are lengthened to a marked extent, whilst the rump and foot segments, and especially the latter, become or remain relatively short and unimportant. The neck frequently becomes so slender that the mastax is pushed backwards into the last segment of the neck when the animal is crawling, and into the anterior segment of the trunk or central body when it is feeding. The increasing distance from the mouth to the mastax necessitates in turn a longer gullet, which is fully but not tensely stretched out when the animal displays its corona. When the latter is withdrawn, the inversion of the mouth reduces the distance to the mastax, and the connecting gullet becomes slack. In extreme cases the slackness is so great that the gullet, which is usually a little stouter near the mastax, bends over, just above the stouter part, towards the ventral side, and so forms a loop, which is not straightened out until the corona is again everted. It is very difficult to see the loop distinctly. The animal must be observed in side view and at the moment when the neck is fully extended, for the gullet is not truly "looped" if it straightens out before the eversion of the corona.

In some species a further modification is seen. Not only is the mastax shifted rearwards, but also the brain, which is normally so placed that the narrow anterior end is close to the dorsal antenna, while the broader posterior part more or less overlaps the mastax. In *H. insignis* the anterior end of the brain is placed about one-half the brain-length behind the antenna, and this also is best seen in lateral view. I find that this modification of the position of the brain does not obtain in all the slender-necked Habrotrochae, and it seems therefore to be a character useful for the differentiation of such species.

Habrotrocha insignis, again, is one of the few species of Bdelloid

Rotifera which not only can endure life in the most exposed situations, but which even seems to prefer it. It would be difficult in Great Britain to find mosses growing in bleaker places than on the tops of the Scottish and Welsh mountains, yet wherever in such elevated places mosses can be found growing and braving the storms, this species, sheltering in the moss-tufts, seems able to flourish exceedingly well.

In many respects the new species *Habrotrocha sylvestris* is closely allied to *H. insignis*, but the upper lip is not so high, and lacks the curious stiffening so distinctive in the latter. On the other hand *H. sylvestris* has a unique character of its own. In certain Distylae (for example, *D. depressa*) the lower end of the oesophagus (which seems to project into the stomach cavity) has an incessant undulatory movement. I found a similar movement of the oesophagus in *H. sylvestris*, where it has probably some connection either with the formation of the food-pellets or with their discharge into the stomach.

Both *H. insignis* and *H. sylvestris* are probably of near relationship to *H. tridens* (Milne), which, however, I judge, from the description and figure given, to be an altogether more slender and cylindrical animal than either. I have not been able to identify it with certainty.

The third species described, *Habrotrocha pavida*, is of quite a different type, and is notable for its moderately wide corona, and the bulging lateral margins of the mouth, which give it a very characteristic outline when favourably seen. Although it has been known to me for many years, it has, with one exception, only been found in moss growing among the grass in a small suburban garden. It is a very timid species, and will rarely feed unless it is ensconced in a convenient "heap" of sand or debris, from which it protrudes its head "at mealtimes." In an earlier paper * I have described the manner in which the food-pellets are moulded in the case of *H. constricta* (Dujardin). In *H. pavida* there is a little more elaboration of the process. If a good lateral view can be obtained while the animal is feeding, the greater part of the oesophagus can be seen, albeit somewhat indistinctly. The inner surface of the tube is apparently lined with cilia, for there is an almost continuous undulatory move-

* Bryce, "Further Notes on Macrotrachelous Callidinae," *Journ. Quek. Micr. Club.*, Vol. V., Ser. II., pp. 436–455. No. 35, 1894.

ment carrying along the food particles towards the end farther from the mastax. Arrived near that end, they become incorporated in a pellet, which is revolved at moderate speed until it is large enough to be expelled into the wide stomach, where its revolving motion ceases. The growth of the pellet at its beginning could not be seen, but perhaps a minute or so after the expulsion of one pellet there could be discerned a tiny mass which, revolving slowly, gradually increased in bulk, the whole process lasting from five to ten minutes if the animal continued feeding steadily. The undulatory movement of the oesophagus seemed to be similar to that frequently observable in the gullet, and less violent than that of the oesophagus in *H. sylvestris*, and, further, it seemed to cease if no particles of food were being passed along, just as it does in the gullet.

Like all the foregoing species, *Habrotrocha flava*, sp. nov., is a dweller in ground moss, although on one occasion I found it in moss which had been growing on a roof, but becoming detached had rolled into the roof gutter. It is a brightly coloured species, for whilst the whole body in the adult is distinctly yellowish, the colour of the stomach deepens almost to a bright rust-red. The corona has a somewhat unusual structure which I later describe in detail, and the many-toothed rami, the stout foot and wide separation of the spurs make this an easily recognisable species.

A very different habitat is characteristic of *Habrotrocha longula* sp. nov., which shows a preference for mosses and algae, growing in running water in the more mountainous districts, where it is constantly found in company with *Philodina flaviceps* Bryce and *Philodinavus paradoxus* (Murray), which also delight in such situations.* This species has the same habit as *H. pavida* of taking shelter in any available aggregations of sand or debris. The stomach in adult examples is usually vividly coloured in tints of pinkish red. Its elongate form, short foot, and peg-like spurs, held nearly parallel, seem to show relationship to

* I have occasionally met with a form nearly related to *H. longula*, perhaps identical with it, in submerged confervae or mosses growing upon artificially made edges of town ponds and in watercress in a country ditch, but I have not had the opportunity of comparing any of the few examples thus found with my notes or sketches of the form now described.

H. elegans (Milne), which, however, has a narrower corona and a still shorter foot.

Habrotrocha insignis, sp. nov.

Pl. 38, fig. 1.

Specific Characters.—Head and neck long, slender; trunk much stouter; foot very short. Corona narrow, three-fourths of collar width; disks dorsally canted and separated by notch; pedicels rather high, slender, adnate. Upper lip undivided, rising nearly as high as pedicels, centrally rounded, stiffened by rigid bent rod of staple-like outline. Mastax far back; rami with three teeth each. Gullet long and looped. Brain remote from antenna. Spurs short, acute cones, without or with little interspace.

When crawling this species bears some resemblance to *Habrotrocha angusticollis* (Murray), when the latter is seen out of its case. The skin of the long head and neck is so smooth that it has a somewhat bright and tight appearance. That of the trunk is finely punctate or stippled along the longitudinal skinfolds, which are distinctly marked, the four central extending over the preanal segment. In well-grown examples the trunk is somewhat long and so much stouter than the neck as to give a somewhat swollen appearance. It gradually increases in size up to the fourth central segment, the succeeding preanal segment being nearly as large, and the anal much smaller, and so rapidly diminishing to the end of the short three-jointed foot. The slender rostrum has rather prominent lamellae. In front of the antenna is seen within the head a curious structure, which may be likened to a thin, rigid rod bent into the form of a staple, but which may be the thickened margin of a concave plate having that outline. No similar structure has yet been detected in any other species. When the corona is protruded this bent rod or plate is seen to be external on the dorsal side of the upper lip. The points of the uprights are now directed forwards (having pointed backwards while the corona was hidden), and the closed end to the rear, about level with the anterior margin of the base of the retracted rostrum. In dorsal view the uprights diverge very slightly, the points reaching the anterior edge of the upper lip on each side, not far from the centre. In lateral

view they are seen to be curved and to enclose a concave area. Whether bent rod or plate, the structure seems to be a support for the high upper lip, and indirectly for the slender pedicels. The under lip is only moderately prominent, but in lateral view the sides of the mouth seem rather high. Behind the mouth I saw several faintly marked annular plicae. The positions of the mastax and of the brain and the looped gullet have been described above.

The short foot tapers rapidly and is about equal in length to one-sixteenth of the whole body. On the dorsal surface of the proximal joint, just behind the anus, is a strong thickening of the hypodermic skin, conspicuous in lateral view when the animal is extended. When feeding most of the foot is retracted within the body, and the extremity is covered by the rump. When the animal is crawling there is no slithering movement. The antenna is of moderate size.

Like many of its near relatives, this species is exceedingly timid. When it ventures to display its corona it usually adopts very curious positions. A favourite position is attained by the animal bending the head and neck back until the corona nearly touches the rump, and then turning the head half round so that the corona presents a lateral and inverted view. Poses of this character are frequently seen among tube-dwelling species with long, slender necks, and it would not be surprising if *H. insignis* should later be found to belong to this section, although no tube-dwelling habit has yet been observed. It is, of course, equally possible that it may have been a tube-dwelling species in the past.

An example isolated laid eggs of usual type, oval, smooth and hyaline, and measuring 66 $\mu \times 46$ μ.

My largest examples measured about 290 μ in length, the rami 15 μ, the spurs 4 to 5 μ; the corona about 20 μ wide, and the collar about 26 μ.

First obtained in ground moss from Baden (? Schwarzwald) in 1894, and thereafter in moss collected by Mr. D. J. Scourfield on Cader Idris in 1895; in moss from the top of Ben Vrachie (Perthshire) in 1908; in liverwort collected by Mr. G. K. Dunstall near Lynton (North Devon) in 1914, and in rock moss from the summit of Snowdon (Wales), gathered by Mr. Lionel Bennett in the same year.

Habrotrocha sylvestris, sp. nov.

Pl. 39 fig. 2.

Specific Characters.—Head and neck slender, elongate; trunk much stouter. Corona narrow, disks scarcely separated, much canted to dorsal side; pedicels adnate, obliquely truncate, hidden in dorsal view by upper lip, which rises in bold curve nearly to edge of disks, and is centrally obtusely angled and moderately deep. Gullet long, looped. Brain close to antenna. Mastax set far back when feeding. Rami with two and three teeth respectively. Foot short, usually hidden. Spurs short, acute, conical, slender, divergent. Oesophagus with constant (?) undulating movement.

I have seen only some five or six examples of this species, which seems to be closely related to *H. angusticollis*. It differs very markedly in the form of the under lip, which is not produced into a spout-like front, but simply rounded like the edge of a cup. When feeding, a few annular wrinkles are visible on the ventral and lateral surfaces of the head about the level of the retracted rostrum, and to right and left of the antenna are two minute decumbent processes. The animal crawls in a rather leisurely fashion. On one occasion I saw a rough tube, partly secreted, partly of entangled particles, and I have seen eggs measuring about 70 $\mu \times 40$ μ, of normal outline, smooth and hyaline.

I have no record of the length when extended, but estimate it about 220 μ. When feeding, the individual figured measured about 190 μ.

Several examples were found in ground moss collected by Mr. A. W. Sheppard in St. Leonard's Forest, Horsham, in 1909. Another was detected in moss sent me by Mdle. Montet, of Vevey, Switzerland, and one other in moss from the Black Forest, Baden, which the late Mr. John Stevens, of Exeter, had received and kindly shared with me.

Habrotrocha pavida, sp. nov.

Pl. 38, fig. 2.

Specific Characters.—Body gradually increasing to greatest width near rump, thence rapidly diminishing; foot small, of

three joints, hidden except spurs. Corona rather wider than collar, pedicels separated by moderate sulcus. Upper lip low, central portion slightly produced to about level of nexus between pedicels, rounded and undivided. Sides of mouth with strong external prominences. Rami obtusely angled, each with four teeth. Spurs slender, acute, held nearly parallel, sometimes slightly incurved, decurved, claw-like, bases separated by interspace nearly equal to spur length. Toes three, small, conical.

In adults the whole body is tinged with yellow, and sometimes the skin is slightly viscous. It usually attains its greatest width in the hinder part of the fourth central segment, and thence narrows rapidly to the small foot, which is so hidden beneath the rump that even when crawling only the spurs can be seen in dorsal view. In this it resembles *Habrotrocha elegans* (Milne), but the body is generally stouter, the increase in size rearwards more marked, and the spurs are not peg-like. When disturbed it crawls about very actively. The corona is wider than is usual in the genus, exceeding the width of the collar. This is not obvious, for the lateral margins of the mouth have each a strong rounded external prominence, which are visible in dorsal view, and, being exactly at the level of the collar, add to the apparent width of the latter. A similar effect has been seen and described in *Calledina angusta* Bryce, and I have also seen it in *Calledina aculeata* (Milne), but in these species the prominences are angular and rather less conspicuous. The post-oral segment has an annular thickening of the skin, rising to small bosses at right and left of the base of the antenna. The neck and gullet are not unusually long, and the brain is close behind the antenna. The rami are somewhat triangular in outline, and have each four well-marked teeth. When feeding, the foot and the greater part of the rump segments are usually withdrawn or hidden beneath the trunk. The spurs are rather slender and acute, held almost parallel, the inner side almost straight, the outer slightly curved, somewhat decurved and claw-like, and have their bases separated by a moderately wide interspace; altogether they are of an unusual and rather distinctive form.

The stomach usually contains pellets of good size. The process of their formation has been described above.

This very distinct species seems to take up its position in

the leaf axils of certain small ground mosses, and to gather round it an accumulation of particles within which it shelters, and possibly thus makes a tube of a most elementary description. It produces eggs of broadly ovate form, with rather obtuse ends, shells smooth and hyaline, measuring about 76 $\mu \times 51\ \mu$.

Length, extended, about 270 μ; feeding, about 170 μ. Rami, 20 μ. Spurs, 6 μ. Width of corona, 38 μ.

Habitat.—Moss among short grass in my garden, Stoke Newington, and (one individual only) in tree moss from Norton's Heath, Essex.

Habrotrocha flava, sp. nov.

Pl. 38. fig. 3.

Specific Characters.—Corona spreading, yet little wider than collar. Pedicels high, sub-adnate. Upper lip undivided, rising rather high to rounded tip. Neck moderately long; gullet looped; mastax far back; rami with six or seven teeth each. Foot very short and stout; spurs short, strongly decurved, widely separated and diverging; interspace very convex.

A species of moderate size with several distinctive characters. While apparently allied to the long-necked species of the genus, the head and neck are less slender than is customary in that section. The adults are frequently conspicuous from the vivid yellowish red of the stomach and the paler tint of the remainder of the body. The corona appears to be of unusual type. In place of the pedicels being straight, slightly diverging or parallel columns, they seemed to be separated at their bases, to approach each other at half height, and thereafter to diverge; the inner line of each showing thus a bold curve in dorsal view. Yet they seemed to be connected by a delicate membrane from their bases to near the plane of the trochal disks. I could discern on the dorsal line an unusually faint line marking, as I thought, the outline of a very delicate upper lip, and farther back in front of the retracted rostrum a much stronger line moderately curved crossing the head. The head is rather elongate when the corona is displayed, and the mastax is then usually in the first and occasionally in the second trunk segment. The gullet is long and is looped when the animal is not feeding. The anterior of

the brain is a little way behind the dorsal antenna. When feeding, this species usually conceals the whole foot below the rump segments. The foot has, I think, three segments, the second somewhat disk-like and carrying two widely separated spurs, which in dorsal view seem to be short, stout cones, but are really only moderately short and strongly decurved. The interspace between them is strikingly convex, and about 12 μ wide. Two strong and broadly truncate toes were seen repeatedly; a third was possibly present, but not detected. On the post-oral segment there is a small prominence on either side of the short antenna.

Length, 320 μ. Rami, 21 μ. Corona, 23 μ wide.

In ground moss at Mundesley and roof moss at Paston, near Mundesley; also in ground moss collected by Mr. G. K. Dunstall, in Surrey.

Habrotrocha longula, sp. nov.

Pl. 39, fig. 1.

Specific Characters.—Rather elongate and slender; body nearly cylindrical; foot very short. Corona wider than collar; pedicels separated by narrow gap; disks slightly canted to dorsal side. Upper lip rising to moderately high, obtuse, median point. Brain long, anterior close to antenna, posterior just overlapping mastax. Gullet not looped. Rami somewhat triangular, longish, each with five teeth. Spurs short, stout pointed cones, held nearly parallel.

In searching washings of moss or algae from stones in swiftly running streams in hilly districts or near the shores of mountain lakes, one frequently finds this species in numbers, and marching about with much pertinacity, though not with much speed. It attracts attention by its bright colour, the alimentary tract being frequently of a vivid orange-red to pink-red tint, and the remainder of the body of a much paler shade. If left undisturbed, the various individuals take shelter after a time in convenient "heaps" of particles, or of "floccose," and will presently commence to feed and so settle down to satisfy their healthy appetites. I have sometimes been able to see a rudimentary secretion of a case, and have no doubt that a certain amount of

viscous fluid is produced in some such way to bind together the sheltering particles or fibres. In several respects this rotifer has marked affinity to *Habrotrocha elegans* (Milne), which has a similar shelter-taking habit. But the head and the corona are larger in proportion, the foot is less hidden beneath the rump; the spurs are stouter, though rather like in style and pose, and the teeth of the rami are five in number.

When feeding, the animal usually bends the anterior part of the body, protruded from the "shelter," to one side or the other, or even backwards, but I have not seen any extravagant contortions of the neck. It lives fairly well in small troughs, and even in small cells I have kept it for over two months.

The form and proportions of the upper lip as shown in fig. 1*a* (Pl. 39) seem rather distinctive. The lateral margins of the mouth are slightly prominent, but less so than in *H. pavida*. The underlip is slightly produced and spout-like. In one case I saw the pellets being formed at a distance of about 15 μ behind the rami, and the oesophagus seemed to be from 20 to 25 μ long. The pellets made are small to moderate in size. On several occasions the rather long and normally placed brain seemed to me to show reddish blotches as of suffused pigment, but I failed to detect any definite eye-spots, such as are so distinct in the cognate *Habrotrocha collaris* Ehrbg. When apparently fully protruded the dorsal antenna measured about 19 μ. In the feeding position it is inclined forwards, almost resting against the retracted rostrum, but towards the tip it is slightly recurved.

The terminal foot joint is stout at the base, but tapers rapidly, and on two occasions I have seen three short, stout, truncate toes protruded.

The eggs are laid within the "shelter" and are of oval outline, smooth and hyaline; measuring about 57–60 μ in longest, and 39–40 μ in shortest diameter.

Length, 300–350 μ. Spurs, 6 μ. Width of corona, 35–38 μ.

From rock moss from summit of Ben Vrackie, Perthshire (1907). In moss close to a waterfall near Milford, South Wales, collected by Mr. G. K. Dunstall. In ncrustation of stones from Untersee, and in mosses from Mittersee, Lunz, Austria, sent me by Dr. von Brehm, of the Lunz Biological Station (1911–13).

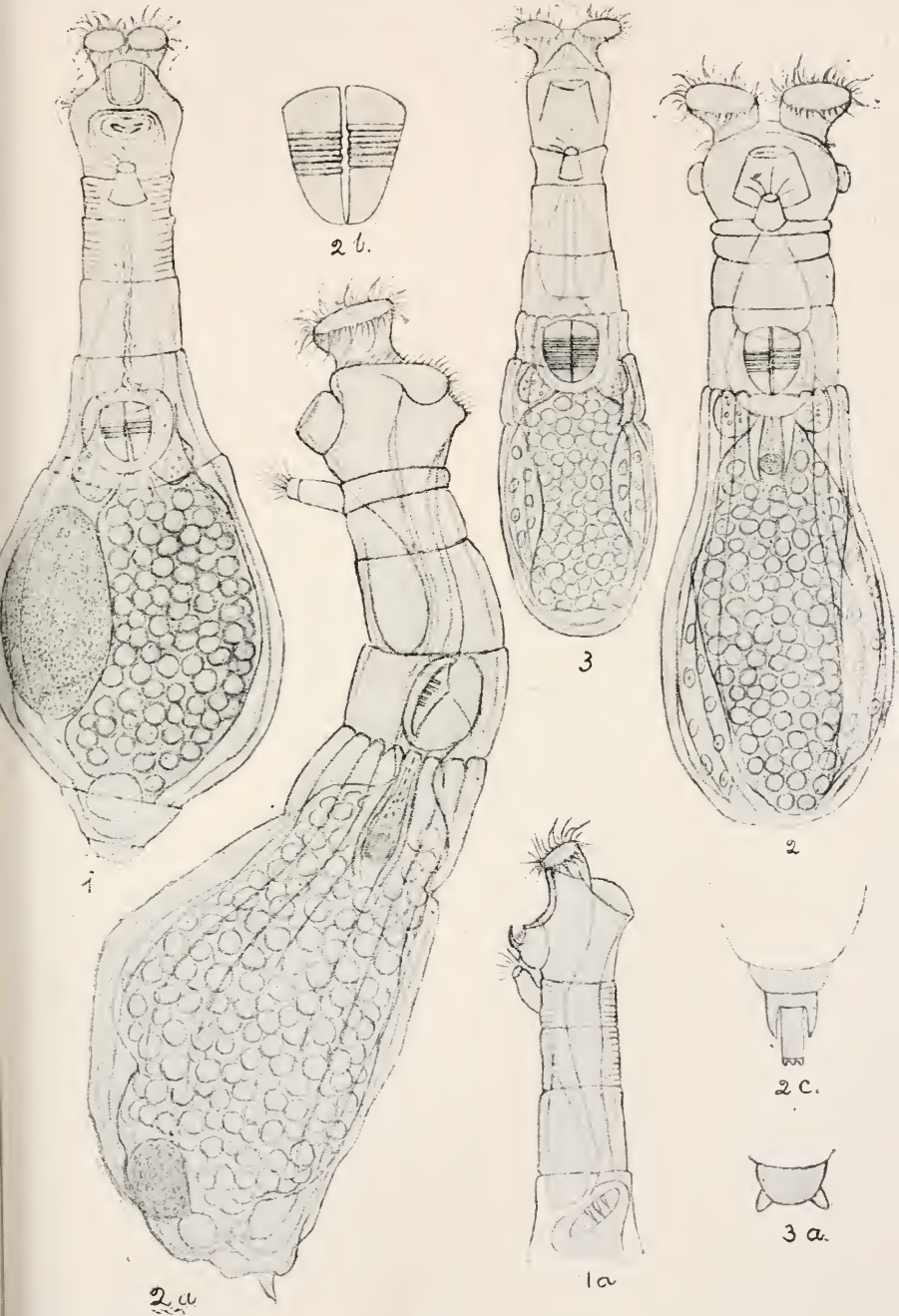
Description of Plates 38 and 39.

Plate 38.

Fig. 1. *Habrotrocha insignis*, sp. nov., dorsal view, feeding position. × 590.
,, 1*a*. Head and neck, corona displayed, in lateral view. × 590.
,, 2. *Habrotrocha pavida*, sp. nov., dorsal view, feeding position. × 590.
,, 2*a*. Same, in lateral view. × 590.
,, 2*b*. Rami. × 1,180.
,, 2*c*. Foot, showing spurs and toes. × 590.
,, 3. *Habrotrocha flava*, sp. nov., dorsal view, feeding position. × 590.
,, 3*a*. Part of foot, showing spurs. × 590.

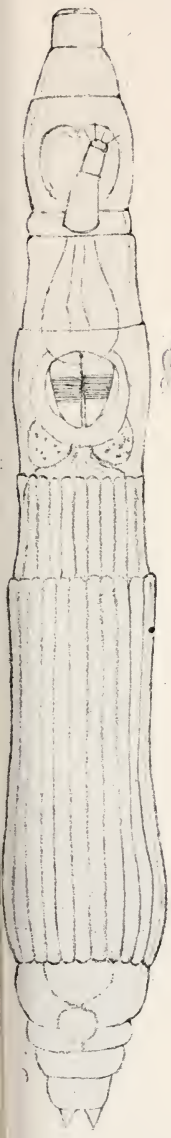
Plate 39.

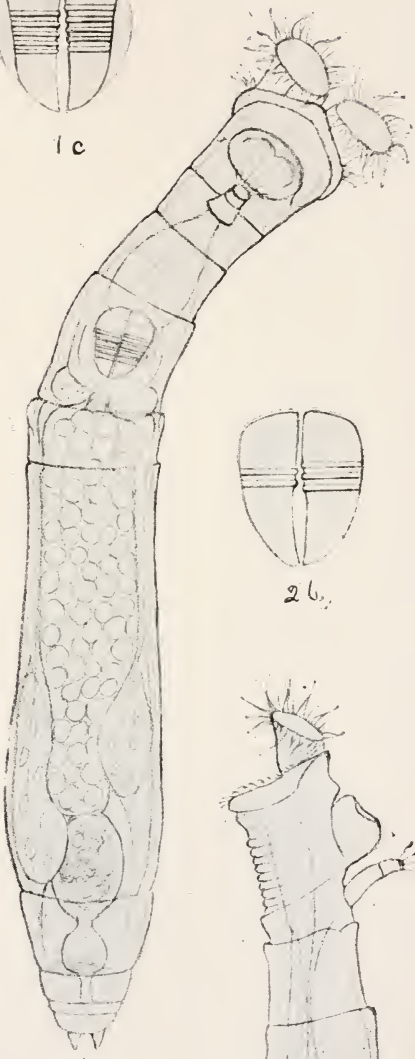
Fig. 1. *Habrotrocha longula*, sp. nov., dorsal view, extended. × 590.
,, 1*a*. Dorsal view, feeding position. × 590.
,, 1*b*. Head and neck, corona displayed, in lateral view. × 590.
,, 1*c*. Rami. × 1,180.
,, 2. *Habrotrocha sylvestris*, sp. nov., dorsal view, feeding position. × 590.
,, 2*a*. Head and neck, corona displayed, in lateral view. × 650.
,, 2*b*. Rami. × 1,180.
,, 2*c*. Spurs. × 590.



D. BRYCE, *del. ad nat.*

NEW SPECIES OF HABROTROCHA.





D. Bryce, *del. ad nat.*

New Species of Habrotrocha.

NOTICES OF BOOKS.

THE BRITISH FRESHWATER RHIZOPODA AND HELIOZOA. By James Cash and George Herbert Wailes, F.L.S., assisted by John Hopkinson, F.L.S., F.Z.S. $8\frac{3}{4} \times 5\frac{3}{4}$. Vol. I. *The Rhizopoda*, Pt. I. x + 150 + 32 pages, 16 plates. 8vo. 1905. Vol. II. *The Rhizopoda*, Pt. II., xviii + 168 + 32 pages, 16 plates and frontispiece. 8vo. 1909. Vol. III. *The Rhizopoda*, Pt. III., xxiv + 156 + 50 pages, 25 plates and frontispiece. 8vo. 1915. The Ray Society. Price £1 17*s.* 6*d.* net.

IT is with great pleasure we draw attention to the publication of the third volume of the above work; this completes the section devoted to the British Freshwater Rhizopoda with the exception of about forty species recorded since 1909, the date when the second volume was issued. It is intended to include descriptions and figures of these species in a fourth and final volume which will also include the British Heliozoa.

From a short history of this work at the commencement of the second volume we learn that Mr. Cash passed away early in 1909 and did not see the completion of that volume. We must congratulate the Secretary of the Ray Society in securing the services of such a competent worker as Mr. G. H. Wailes to complete the work left unfinished by its original author, the third volume which has just been published being by him. Mr. Hopkinson has provided a short memoir of James Cash. Before studying the Rhizopoda he had devoted considerable attention to Bryology, and his collection of drawings and specimens has been presented to the Manchester Museum. When he first turned his attention from the mosses to the rhizopods we do not know, but in 1891 he read a paper before the Manchester Microscopical Society giving the results of his investigations of the Rhizopoda of the Manchester area in the same year. This paper added several species to the British list, and seems to have revived an interest in the fauna of these microscopic creatures. These volumes show how far that interest has been carried and cannot fail to be an aid and incentive to the microscopist in making further records of the

rhizopodal fauna of the districts in which they reside. In this connection it may be remarked that with the exception of Loch Ness not one of the larger British lakes has been investigated as to the rhizopodal fauna of either the plankton or deposits, a large and unworked field awaiting investigation. To the microscopist desirous of working in this interesting department of micro-fauna we may draw attention to two papers recently published: (1) Dr. Eugène Penard, "Collection and Preservation of Freshwater Rhizopoda," *Journ. Q.M.C.*, Vol. X., pp. 107–116; (2) G. H. Wailes, "Notes on the Structure of Tests of Freshwater Rhizopoda," *Journ. R.M.S.*, April, 1915, pp. 105–116, 2 plates.

In the third volume of *The British Freshwater Rhizopoda* there are twenty-five plates from drawings made by Mr. Wailes, a larger number than in either of the previous volumes. Of these eight are coloured, and their beauty cannot be too highly praised. Through the courtesy of the Secretary and Council of the Ray Society we are able to present our members with a copy of Plate XLIV. The uncoloured plates are in collotype, and are, we think, a great improvement on the half-tone reproductions which appeared in the previous volumes. The frontispiece to this volume is a particularly interesting one, being reproductions in collotype of photo-micrographs from preparations made by Dr. Eugène Penard, of Geneva.

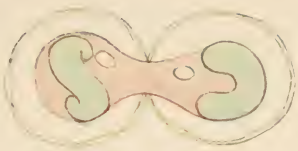
In the case of all three volumes Mr. John Hopkinson has been responsible for the synonymic references, and the amount of labour and critical insight that he has devoted to this share of the work can only be fully realised by one who has done similar work. The arrangement of the references in this volume is an improvement on that of the two previous volumes.

Description of Plate 40.*

Paulinella chromatophora Lauterborn. Figs. 1, 2: Side view and transverse section of an active individual. × 1,500. Fig. 3: Process of division. × 1,500. Fig. 4: Nucleus. × 2,000. All after Lauterborn.

P. chromatophora var. *pulchella* (G. S. West) Wailes. Figs. 5, 6:

* *British Freshwater Rhizopoda*, Vol. III., Pl. XLIV.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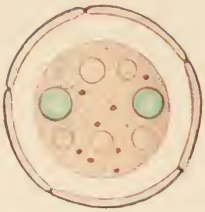
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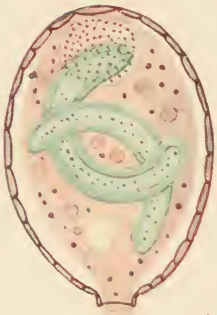
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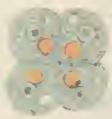
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12

RHIZOPODA.

Oral and side views, after West. × 750. *P. chromatophora* Lauterborn. Figs. 7, 8: Side and oral views, after Brown. × 1,200.

Lecythium hyalinum Hertwig and Lesser. Fig. 9: Solitary active individual. Fig. 10: Appearance of same when deprived of air. × 500. *L. granulatum* (Schulze) Hopkins. Fig. 11: Individual distended by ingested diatoms; from a specimen stained and mounted by Dr. Penard. × 300.

Diplophrys archeri Barker. Fig. 12: Active solitary individual. Fig. 13: Process of tetrad division, after Hertwig and Lesser. × 1,000.

MARINE BIOLOGICAL LABORATORY
WOODS HOLE
LIBRARY
MASS.

THE CLUB CABINET.

The following Slides have been added to the Cabinet since October 1914 :

Echinodermata.

Presented by C. J. H. Sidwell.

N. 32. Spicules of *Plexaura flexuosa.*

Rotifera.

Presented by C. F. Rousselet.

Series 21. *Typical genera.*

Anuraca aculeata (Ehrenberg).
Asplanchna Brightwelli (Gosse), ♂ and ♀.
Brachionus pala (Ehrenberg).
Cathypna luna (Ehrenberg).
Euchlanis hyalina (Leydig).
Hydatina senta (Ehrenberg), ♂ and ♀.
Lacinularia socialis (Ehrenberg).
Metopidia lepadella (Ehrenberg).
Notholca scapha (Gosse).
Polyarthra platyptera (Ehrenberg).
Rhinops nitrea (Hudson).
Synchaeta tremula (Ehrenberg).

Insecta.

Presented by the late Prof. E. A. Minchin.

Series 22. Anatomy of the Rat Flea (*Ceratophyllus fasciatus*). Twenty-four Slides of dissections of the nervous, genital and salivary systems, etc., with descriptive text and plates.

Mycetozoa.

Presented by C. H. Huish.

C.A. 1. *Arcyria cinerea* (= *albida*).
2. *Arcyria ferruginea.*
3. *Badhamia rubiginosa*, var. *dictyospora.*
4. *Ceratiomyxa fructiculosa* (= *mucida*).
5. *Diachoea leucopoda* (= *elegans*).
6. *Dictydium cancellatum* (= *umbilicatum*).
7. *Didymium dubium.*
8. *Didymium melanospermum* (= *farinaceum*).
9. *Lamproderma columbinum.*
10. *Physarum contextum.*
11. *Physarum viride.*
15. *Trichia botrytis*, var. *lateritia.*

Musci.

Presented by G. T. Harris.

Classification from Dixon's *Student's Handbook of British Mosses*, second edition.

D.A. 6. *Amblystegium serpens.*
7. *Amblystegium varium.*
8. *Barbula lurida.*
9. *Barbula rubella.*
10. *Barbula tophacea*, peristome.
11. *Barbula unguiculata.*
12. *Barbula unguiculata*, peristome.
13. *Brachythecium populeum.*
14. *Brachythecium rutabulum*, var. *longisetum.*
15. *Brachythecium rutabulum*, peristome (opaque).
16. *Brachythecium rutabulum*, peristome.
17. *Brachythecium rutabulum*, leaves of type.
18. *Brachythecium velutinum.*
20. *Bryum atro-purpureum*, var. *gracilentum.*
21. *Bryum capillare*, peristome.
23. *Bryum pallens*, "female flower."
24. *Campylopus flexuosus.*
25. *Catharinea undulata*, peristome.
26. *Ceratodon purpureus.*

D.A. 27. *Cryphaea heteromalla*, leaves.
28. *Cryphaea heteromalla*, peristome (opaque).
29. *Dicranella heteromalla.*
30. *Dicranella rufescens.*
31. *Dicranella varia.*
32. *Dicranum majus*, leaves to show pores.
33. *Dicranum scoparium*, peristome (opaque).
34. *Dicranum scoparium*, peristome.
35. *Eurhynchium confertum.*
36. *Eurhynchium myosuroides.*
37. *Eurhynchium myosuroides*, "female flower."
38. *Eurhynchium pumilum.*
39. *Eurhynchium Swartzii.*
40. *Fissidens algarvicus.*
41. *Fissidens bryoides.*
42. *Fissidens bryoides, forma inconstans.*
43. *Fissidens Curnowii.*
44. *Fissidens exilis.*
45. *Fissidens incurvus*, var. *tamarindifolius.*
47. *Fissidens rivularis.*
48. *Fissidens taxifolius.*
49. *Fissidens viridulus.*
50. *Funaria fascicularis.*
51. *Funaria hygrometrica*, peristome.
52. *Grimmia apocarpa.*
53. *Grimmia apocarpa*, peristome.
54. *Grimmia pulvinata.*
55. *Hedwigia ciliata*, leaves.
56. *Hylocomium squarrosum*, peristome.
57. *Hypnum cupressiforme*, type.
58. *Hypnum cupressiforme*, leaves of type.
59. *Hypnum cupressiforme*, "male flower."
60. *Hypnum cupressiforme*, var. *filiforme.*
61. *Hypnum cupressiforme*, var. *resupinatum.*
62. *Leucobryum glaucum*, leaves.
63. *Neckera pumila.*
64. *Neckera pumila*, archegonia.
65. *Orthotrichum affine*, leaves and "female flower."
66. *Orthotrichum affine*, to show superficial stomata.
67. *Orthotrichum affine*, peristome (opaque).

D A. 68. *Orthotrichum diaphanum*, to show "immersed" stomata.
69. *Orthotrichum diaphanum*, peristome (opaque).
70. *Orthotrichum Lyellii*, leaves bearing gemmae.
71. *Plagiothecium elegans*, showing flagellae.
72. *Pleuridium subulatum*.
73. *Polytrichum formosum*, sections of leaves to show lamellae.
74. *Pottia lanceolata*.
75. *Pottia truncatula*.
76. *Pterygophyllum lucens*.
77. *Rhacomitrium lanuginosum*.
78. *Sphagnum acutifolium*, branches.
79. *Sphagnum acutifolium*, to show " retort " cells.
80. *Sphagnum cymbifolium*, stem to show spiral vessels.
81. *Sphagnum rigidum*, var. *compactum*.
82. *Tortula aloides*.
83. *Tortula laevipila*.
84. *Ulota phyllantha*, leaves.
85. *Webera carnea*.

Plant Structure (Cellular).

Presented by C. J. H. Sidwell.

D.B.* 29. Leaf of Holly Fern.
30. Leaf of *Hymenophyllum Tunbridgense*.
E. 36. Leaf of *Althaea rosea* : Hollyhock.
E.A. 59. Leaf of *Pinguicula vulgaris* : Butterwort.

Seeds.

Presented by C. J. H. Sidwell.

G. 48. *Orthocarpus* sp.
49. *Pterospora andromedea*.
2. *Spergula minor*.

Fossil Botany.

Purchased. J. Lomax, preparer. 3 in. by 2 in. slips.

The figures in ( ) refer to illustrations in Dr. D. H. Scott's *Studies in Fossil Botany*, 2nd edition (copy in Q.M.C. Library).

Localities: all preparations from Shore, Littleborough, Lancs., unless otherwise indicated.

Y.C. 1. Tr. sec. of a large stem of Calamites.

2. (A) Tr. sec. of stem of Calamites, with portion of cortex (figs. 4 and 5); (B) portion of a cone of *Calamostachys Binneyana*; (C) a root of Calamites.

3. (AA) Tr. secs. of stems of Calamites; (B) tr. sec. of small rootlet, probably of Amyelon; (CC) tr. secs. of *Amyelon radicans* (? the root of one of the Cordaiteae); (D) leaves of Cordaites; (E) megasporangia containing megaspores.

4. (AAA) Tr. secs. of Astromyelon (? the root of a Calamites); (B) portion of a cone of *Calamostachys Binneyana*.

5. (A) Tr. sec. of a splendid cone of *Calamostachys Binneyana*, with sporangia full of spores (fig. 18); (BB) tr. and long. sections leaves of Calamites (fig. 14); (CC) leaves of Sigillariopsis; (D) seed of *Physostoma elegans*. Locality: Halifax Hard Bed, Huddersfield.

6. Long. sec. cone of *Calamostachys Binneyana* (fig. 17). Locality: Halifax Hard Bed, Huddersfield.

7. Tr. sec. stem of *Sphenophyllum plurifoliatum* (fig. 38).

8. Long. sec. cone of *Sphenophyllum Dawsoni*, showing bracts, etc., at A, and sporangia containing spores at B (figs. 42–44).

9. Tr. sec. stem of *Lepidodendron selaginoides*. Locality: Halifax Hard Bed, Huddersfield.

10. (A) Tr. sec. stem of *Lepidodendron selaginoides* (figs. 59 and 60); (B) tr. sec. stem of *Lepidodendron macrophyllum*. Locality: Cloughfoot, Dulesgate, near Todmorden.

11. Tr. sec. stem of *Lepidodendron fuliginosum*.

12. Tr. sec. stem of *Lepidodendron Harcourtii*.

13. Tr. sec. stem of *Lepidodendron Harcourtii*, showing at (A) the stele with primary and secondary xylem, (B) inner cortex, (C) outer cortex, and (D) leaf-bases (fig. 56).

14. Tang. sec. leaf-bases of stem of *Lepidodendron Har-*

courtii (Lepidophloios). In many of the leaf-bases the vascular bundle, parichnos strands and ligule are seen (fig. 62).

Y.C. 15. (A and B) Tr. secs. stems of *Bothrodendron mundum* ; (C) tr. sec. of a similar, but much smaller, stem.

16. Tr. sec. cone of *Lepidostrobus oldhamius* with microspores.

17. Tr. sec. cone of *Lepidostrobus oldhamius*. This cone does not contain any spores, but the axis and laminae are well shown.

18. Tr. sec. portion of *Stigmaria ficoides*, showing at A the zone of wood, with cortex and rootlet-bases at B and C (figs. 98 and 100).

19. Tang. sec. *Stigmaria ficoides* through outer cortex, cutting rootlets transversely (fig. 97).

20. Tang. sec. *Stigmaria ficoides* through zone of wood (fig. 99).

21. Radial sec. *Stigmaria ficoides*.

22. Tr. sec. *Stigmaria* sp., showing zone of wood at A, and cortex with rootlet-bases at B.

23. Tr. sec. stem of *Etapteris Laceattei*.

24. Tr. sec. stem of *Metaclepsydropsis duplex*. Locality : Pettycur, Burntisland, Fife.

25. Tr. secs. stems of *Botryopteris cylindrica*, the one at B being cut at junction with petiole. Locality : Halifax Hard Bed, Huddersfield.

26. Tr. sec. stem of *Zygopteris bibractensis* (fig. 118).

27. Tr. secs. stems and petioles of *Stauropteris oldhamia* (figs. 126–128).

28. Tr. sec. stem of *Lyginodendron oldhamium* (fig. 129).

29. Tang. sec. stem of *Lyginodendron oldhamium*, rootlets being given off at A (figs. 138 and 142).

30. Radial secs. stem of *Lyginodendron oldhamium*, rootlets being given off at A (figs. 138 and 142).

31. (A) Tr. sec. young stem of Lyginodendron ; (BB) leaf-rachis ; (C) root. Locality : Dulesgate, near Todmorden.

32. (A) Tr. sec. leaf-rachis of *Lyginodendron oldhamium* ; (B) tr. sec. young stem ; (CC) tr. secs. of roots (figs. 139, 141 and 145). Locality, Dulesgate, near Todmorden.

Y.C. 33. (A) A practically perfect long. sec. seed of *Physostoma elegans*, passing through the micropyle, and showing pollen-chamber containing pollen-grains; (BB) synangia of *Telangium Scottii*, the microsporangia of Lyginodendron.

34. (A) Tr. sec. through the centre of a seed of *Physostoma elegans*; (B) tr. sec. of a Fern stem.

35. Tr. secs. stems of *Heterangium Grievii* (fig. 154). Locality: Pettycur, Burntisland, Fife.

36. Tr. sec. stem of Cordaites (Mesoxylon) (fig. 189).

37. (A) Tr. sec. portion of stem of *Mesoxylon multirame*; (B) root of Lyginodendron.

38. Tr. secs. *Amyelon radicans* (? the root of one of the Cordaiteae) (fig. 191).

39. Splendid tr. sec. of a leaf of Cordaites (fig. 192).

40. Three sections of seeds of *Mitrospermum compressum*.

PROCEEDINGS

OF THE

QUEKETT MICROSCOPICAL CLUB.

At the 506th Ordinary Meeting of the Club, held on March 23rd, Vice-President D. J. Scourfield, F.Z.S., F.R.M.S., in the chair, the minutes of the meeting held on February 23rd were read and confirmed.

Messrs. Joseph Longmore and Joseph Lovelace Ribbons were balloted for and duly elected members of the Club.

It was announced that ninety slides had been added to the Cabinet of microscopic objects. Fourteen of these were presented by Prof. E. A. Minchin, in illustration of his paper read to the club recently on "Some Details in the Anatomy of the Rat-flea," and were in addition to those given on that occasion, and seventy-two were presented by Mr. G. T. Harris, illustrating his paper on Bryological Work.

At the request of the Chairman, Mr. C. D. Soar, F.L.S., F.R.M.S., then read a *résumé* of a paper by Mr. Williamson and himself, on the "British Hydracarina, genus Lebertia." Mr. Soar said the genus Lebertia has been rather neglected. It is certainly a difficult group. The species appeared to run into one another so closely that identification was rendered very uncertain. However, Dr. Sig Thor, of Norway, at last took this genus in hand. He divided it into sub-genera, and went one by one through every species that had been recorded, publishing altogether in the *Zoologischer Anzeiger* over thirty papers on this genus alone. Finding the way thus prepared for us, Mr. Williamson and myself have worked out the material which we had been collecting together for some years, and the paper to-night is the result. In the posthumous memoir of Leberts, published in 1879, he describes and figures a Hydracarid, which he considered new on account of the form of the genital area. This mite he named *Pachygaster tau-insignitus*. He explains the specific name by referring to the

resemblance which the light dorsal marking bore to the Greek letter tau. The generic name was altered to Lebertia (after Leberts) by Neuman, in 1880. Sig Thor has now divided the genus into five sub-genera. These are as follows: 1, Lebertia; 2, Pilolebertia; 3, Mixolebertia; 4, Pseudolebertia; 5, Hexalebertia. Three of the type species have been found in the British area. The type species *L. tau-insignitus* at present has only been found in the Lake of Geneva. But, being the type, we have thought it right to include a description for comparison. We have about ten species for the British area. One species, *Lebertia trisetica* (Sig Thor), sub-genus Hexalebertia, was found in Surrey in 1896. It was sent to Sig Thor, who named it in 1900; two specimens were taken at the time, but it has never been recorded since. Several of the ten species have already been recorded, but never fully described in Britain.

Mr. J. W. Gordon exhibited and described an objective of the same type as that described by Mr. E. M. Nelson in the last number of the Journal of the Club, as being the latest production of Messrs. Zeiss. Mr. Gordon explained that his lens—a 1/2-in. dry lens, fitted with a front carrying an oil-immersion lens, had been constructed for him by Messrs. Beck so far back as July 1909, that he has had it in use ever since, had shown it to various persons, and that the lens had been described in the catalogue of the Optical Convention of 1912. The following is the description which appeared there: "The use of oil-immersion has hitherto been confined to objectives of the 1/8th-in. and 1/12th-in. class under an impression, which proves to be mistaken, that oil-immersion secures no particular advantages when applied to objectives of lower power. The model is a 1/2-in. dry lens fitted with a supplementary lens of rather less than hemispherical angle, mounted so that the centre of the sphere lies in the object. The spherical surface, therefore, produces no refraction, and its addition to the optical system involves no change in the correction of an objective adjusted for viewing an uncovered object. The abolition of the top surface of the cover-glass, by oiling on the supplementary front lens produces an increase of 50 per cent. in magnifying power, and a commensurate increase in light-gathering power. The catoptric haze produced by internal reflection from the front face of the permanent front lens sinks into comparative insignificance, and

a 1/2-in. dry lens is converted into a 1/3rd-in. immersion system of much improved defining power."

Mr. G. T. Harris, of Sidmouth, formerly a member of the Club, had presented to the Cabinet 72 micro. preparations of various mosses. He accompanied them with a paper on "Microscopical Methods in Bryological Work," which was read by Mr. F. J. Perks. It was pointed out that mosses did not appeal very strongly to microscopists *per se*, as the work to be done with them is mostly systematic, and they yield but few "display" objects. The earlier bryologists relied mainly upon herbarium sheets for the preservation of their specimens and for identification purposes—a plan sufficient at a time when the division of the group into species, sub-species and varieties was not carried out to the extent it is now. Thirty years ago specific distinctions were largely dependent upon general habit and the presence or absence of the so-called "nerve" and the nature of the leaf margin. But no bryologist of the present day would care to decide upon specific names without microscopic assistance. The impossibility of securing the perfect cleanliness so desirable in microscopical mounts with moss specimens was pointed out, the plants growing usually in mud, or dirty situations, and, owing to their fragile constitution, not bearing any cleaning process without damage. Probably most bryologists relied on glycerine jelly for mounting. Some years ago Mr. Harris prepared a considerable collection of Hypnaceae in this medium, but in about twelve months found the whole of them so deteriorated as to be of no value. As in other instances the result had been successful, he concluded the difficulty arose from avoidable causes. In his paper he gave various precautions that should be observed in using glycerine jelly. Farrant's medium probably comes next to glycerine jelly in usefulness; it is very convenient to use, and, of course, allows of great deliberation in arranging the object. For peristomes, which require to be examined by transmitted light, it is excellent. Other mediums having various advantages were then referred to, particularly two, having copper acetate in their composition, one with glycerine and the other with potassium acetate; formalin was also noticed. Cases in which difficulty arose owing to the dark colour and want of transparency of the leaves, and where manipulation was not easy owing to structure, were noted,

and hints given for overcoming the troubles. The treatment for satisfactorily displaying the capsule, with its peristome, was entered upon at some length, and a reference made to the section-cutting required, in order to render evident the component cells of the stem and leaves. Finally the necessity for a collection of slides as an assistance to identification was insisted upon in the following paragraph: "Fifty years ago English bryologists considered themselves well served with ten species of Sphagna, the separation of which was no great strain on one's mental powers. At the present time it is useless to touch the group unless you are prepared to distinguish between at least forty species, with an average of four varieties each. Of *Sphagnum acutifolium* alone, Warnstorf describes sixty varieties. It will be seen from this how valuable an authenticated collection of slides would be to the bewildered student." Dixon's *Student's Handbook of British Mosses* was recommended as a handbook to any one taking up the study of the group.

The paper was most valuable from a practical point of view, and would no doubt have led to an interesting and useful discussion; but, unfortunately, owing to the lateness of the hour, this was altogether impossible.

Votes of thanks to the donors of the slides added to the Cabinet, and to the authors of the interesting communications brought before the meeting, were proposed from the chair, and carried unanimously, with great heartiness.

At the 507th Ordinary Meeting of the Club, held on April 27th, the Hon. Treasurer (Mr. F. J. Perks) in the chair, the minutes of the meeting held on March 23rd were read and confirmed.

Messrs. William Williamson, Roy Gerald Evans, John Richard Duncanson, Walter Lauwers and the Rev. S. Rennie Craig were balloted for and duly elected members of the Club.

A hearty vote of thanks was returned to Dr. E. J. Spitta for a presentation of lantern slides of historical interest to the Club, which had been previously exhibited to the members at the 500th meeting. The lantern slides in question were placed upon the table for the inspection of the members. The members also thanked Mr. C. Huish for presenting to the Club one dozen slides of Mycetozoa. Amongst the additions to the Cabinet it

was mentioned that 40 slides illustrative of Palaeozoic Botany had been purchased.

Mr. Ainslie, R.N., then introduced the following paper, entitled "An Addition to an Objective": Few microscopists who have made much use of high-power dry objectives have failed to realise the connection between the tube-length and the thickness of the cover-glass if good definition is to be obtained. This is, indeed, mentioned in the textbooks, but not, as a rule, at very great length. Little is said, for instance, as to the amount of alteration required in any given case. The sensitiveness of objectives varies enormously; to a certain extent with the formula on which the objective is constructed, but more especially with the power. As an example, a 1/2-in. of high aperture, such as the Holos or the Zeiss Apochromat, requires a change of one or two millimetres only in the tube-length to compensate for a change of 0·01 mm. in the thickness of the cover-glass; for 1/6th, the figure is from 9 to 13, while for a 1/8th, such as the Leitz No. 7, the figure is as much as 20 or 21. Water-immersions are also subject to this sensitiveness, though to a smaller extent, the figure in the case of a Zeiss "G" being 9·2. This feature is more important than is often realised, and the difficulty caused thereby is enhanced by the extremely small range of draw-tube in the average Continental stand, and unfortunately, in many stands of English make. The present paper is an attempt to find a way out of the difficulty, and the device suggested should be useful when the range of draw-tube is insufficient, especially when the higher powers are in use. Many years ago the celebrated Van Heurck used what he called a "transformer" as a means of making a long-tube objective work on a short tube, and vice versa. This consisted of a convex or concave lens of low power, fitted above the objective, which, it will be readily understood, affords a means of altering the actual plane in which the image is formed (without affecting the action of the objective), should it happen that the cover-glass is of such thickness to require, for satisfactory definition, a tube-length which would bring the image beyond the limits of the draw-tube. With the high-power dry objectives in common use, such as the average 1/6th, the power of the additional lens required to effect the compensation for a considerable change of cover-thickness is not excessive; a pair of lenses,

convex and concave, of about 3 diopters power, or about 13 in. focus, will suffice to correct for a very considerable range of cover-thickness; but with higher powers, such as a 1/8th, the amount of correction which can be got in this way is a good deal less. This might be expected, from their greater sensitiveness to cover-thickness. As an example of what can be done with an objective not too high in power, it may be said that a Watson 1/6th, of N.A. 0·74, which is normally corrected for a cover 0·18 mm. thick, and a tube-length of 200 mm., can be made to work well through a cover-glass as much as 0·50 mm. in thickness, if a concave lens of −8 diopters be placed behind it, while with a convex lens of the same or somewhat lower power it will work well on an uncovered object; and most other objectives of this power will do as well. I have so far only experimented with simple lenses; but the chromatic and spherical corrections of the objective are not perceptibly affected, unless the power of the additional lens is as much as 10 diopters, and even then the effect is not serious, and is not appreciable at the centre of the field. The magnifying power of the objective is somewhat reduced by the convex lens, as well as the N.A., while with the concave lens the effect is the opposite; but the change is not great if the additional lens is placed as near to the back lens of the objective as possible, though it does very well in practice to place it behind the objective mount. There is yet another use to which this additional lens may be put, which, so far as I know, has not been previously described. If for the oil in which an oil-immersion objective is immersed we substitute water, the effect is just the same in kind as that of a reduction in cover-thickness, though greater in degree; and it has been found possible to convert an oil-immersion into a very good water-immersion by merely fitting behind it a convex lens of suitable power. The power of the convex lens cannot be predicted, but must be determined by trial for each objective.

It is easier to effect the conversion in the case of an oil-immersion of moderate power, such as 1/10th, than in the case of a 1/12th or higher power, though a 1/12th can be dealt with very satisfactorily if its working distance is not too small. A Watson "Parachromatic" 1/12th, for example, requires a convex lens of 10 diopters. It is important, in the case of a lens of this power, to place the additional lens as near as possible to the

back lens of the objective; this minimises the unavoidable loss of working distance. The additional lens may very conveniently be fitted to the "funnel stop" commonly supplied with oil-immersions to reduce the aperture for dark-ground illumination. With an oil-immersion thus converted to a water-immersion, it is useless to expect that the whole aperture will be available; the corrections of the objective are far too much upset for that; but if the additional lens is made of such diameter as to reduce the N.A. to about 1·1, and if an illuminating cone not exceeding N.A. 0·75 or 0·8 be employed, the performance is in all the cases tried quite up to the standard of the ordinary water-immersion and better than some. It should not be forgotten that the substitution of water for oil renders the objective sensitive to changes of cover-thickness, and the tube-length will have to be carefully adjusted to compensate for this. It is hoped that this method of converting an oil-immersion into a water-immersion may be found of use, especially to those who occasionally require to use a water-immersion for work on living specimens, or in other work for which an oil-immersion would be inconvenient.

Objects were exhibited under microscopes kindly lent by Messrs. H. F. Angus & Co., and by Messrs. W. Watson & Son, to illustrate the paper; these were:

1. A specimen of polished steel, with a Watson 4 mm. apochromatic, N.A. 0·85, a convex lens of 6 diopters being used to correct for the absence of a cover-glass. (Magnifying power, 340 diameters.)

2. *Bacillus typhosus*, showing flagella, with a Watson 1/6th, N.A. 0·74, an extra cover being introduced to bring the total thickness up to 0·50 mm. and a concave lens of −8 diopters being introduced. (510 diameters.)

3. Tubercle bacillus, with a Watson 1/12th oil-immersion, N.A. 1·3 working with a water-immersion, a convex lens of +10 diopters being introduced to effect the conversion. (940 diameters.)

The Hon. Secretary (Mr. F. Burton) then read "Notes on a Diatom Structure," by Mr. A. A. C. Eliot Merlin, F.R.M.S. The author drew attention to a very beautiful form of tertiary structure he recently found on a variety of *Aulacodiscus comberi* from Oamaru. The valve is on a styrax type slide of 230 forms

from that locality, and is covered with a network of dark, well-defined secondaries, except on the parts occupied by the large primaries. Each of the dark secondaries splits up into three or four parts by a bright cross-bar arrangement. This structure requires a good oil-immersion objective and a very considerable magnification to render it readily discernible.

A photograph of the above was exhibited, and Mr. E. M. Nelson, F.R.M.S., confirmed the presence of this structure from a specimen in his cabinet. Mr. Merlin also exhibited two other photographs of a diatom. Mr. Nelson had written him that he had discovered that *Coscinodiscus simbirskii*, which, with ordinary transmitted light, resembles *Coscinodiscus asteromphalus*, when examined with a dark ground and a rather small stop looks like *Actinoptychus splendens*. This led him to search for the diatom specified, and although this could not be found, he found one which, with a dark-ground illumination, revealed a beautiful radiating structure, somewhat resembling a Heliopelta, which was not observable by transmitted light. On the photographs of this specimen being examined it was identified by Mr. Morland as *Janischia antiqua*, Grunow. Mr. Merlin further pointed out that, although diatom-dotting has influenced the development of the microscope towards perfection more than anything else, he is unable to find out particulars of its introduction. Mr. Nelson sent an extract from Messrs. Sollitt and Harrison's paper, read before the British Association at Hull in 1853: "We in Hull first discovered the delicate markings on their silicious coverings, and pointed them out to others as the proper tests for lenses. The first of the Diatomaceae on which the lines were seen was the *Navicula hippocampus* of Ehrenberg—this was early in 1841, when specimens were sent to the Microscopical Society of London—also to Mr. Smith, Mr. Ross, Messrs. Powell & Lealand, M. Nachet in Paris, and Professor Bailey in America, all of whom at once saw the excellency of these objects as tests for the microscope."

At the 508th Ordinary Meeting of the Club, held on Tuesday, May 25th, the Vice-President, Mr. D. J. Scourfield, F.Z.S., F.R.M.S., in the chair, the minutes of the meeting held on April 27th were read and confirmed.

Messrs. Sydney Harold Robinson, Walter E. T. Hartley and John F. Donald Tutt were balloted for and duly elected members of the Club.

The Hon. Secretary announced the presentation to the Club's Cabinet of a further five slides of rare mosses by Mr. G. T. Harris. Also an addition to the Club's album of a photograph of Mr. G. C. Karop, who was Secretary of the Club from 1883 until February 1904.

Mr. Seabury Edwardes, F.R.M.S., contributed a paper giving some practical details on mounting diatoms in phosphorus. The paper was read in abstract by the Hon. Secretary, but whether any member has the temerity to put Mr. Edwardes' directions to a practical test seems very doubtful. The results even on the author's showing are somewhat problematical, and the process very dangerous. It is hardly likely to come into use, as there are simpler methods of mounting diatoms in high refractive media.

Further notes on the cultivation of plasmodia of *Badhamia utricularis* were given by Mr. A. E. Hilton. A year ago he called attention to a method of cultivating this plasmodium on bread, with occasional applications of a solution of ammonium phosphate and cane-sugar. In the discussion following, two points were raised which he was unable to answer. One was whether this particular species of Mycetozoa could be obtained by the cultivation of spores; the other, whether it would, when artificially fed, form sporangia. As a result of further investigation, Mr. Hilton stated that it is possible to cultivate the spores, but not always easy. With regard to the second question, whether it would form sporangia when artificially fed, he was now able to state that it would, but with certain reservations. On February 19th last a plasmodium of *B. utricularis* was started by reviving a fragment of sclerotium, which was treated entirely with bread and water and the chemical solution, adding, however, calcium phosphate, with a view to supplying the lime usually found in this form of sporangium. The cold weather made growth slow; but on May 5th the plasmodium changed into a quantity of sporangia. There are striking differences between these and those produced under natural conditions. The shape is similar; but instead of the usual cinereous hue, they are a dull purple-black, cinnamon-brown, or even pale

biscuit tint. All are sprinkled with white crystalline particles. The sporangium walls, usually very thin and fragile, are hard, thick and chippy, and there is no distinguishable capillitium. They are also only about half the ordinary diameter. The spores themselves, generally bright brown and spinulose, are smooth and almost colourless, but quite the usual size, if not slightly larger, and in other respects appear perfectly normal. Mr. Hilton had not yet attempted to cultivate these spores.

The Hon. Secretary then read a paper on *Hydrodictyon reticulatum*, or *utriculatum*. Last September he found an immense quantity of this alga in the lake in Kew Gardens. According to Dr. Cooke the "water-net" is one of the earliest enumerated freshwater algae in Britain. It is figured in Plukenel's *Alma Gestum* in 1691, and was again mentioned by Bobart in 1699. Ray includes it in his "Synopsis" in 1724 as *Conferva reticulata*, and says that it was found in ditches about Westminster and Hounslow. Owing to various characteristics which are not found in other algae, Hydrodictyon has been placed in a subfamily by itself. It consists of a saccate net-like object varying in size from almost microscopic up to a length of several inches. The cells also vary in size when young from 8 μ to 10 μ in diameter and grow sometimes to a length of 1 c.m.—say, 2/5th-in. They are approximately cylindrical in shape, and are arranged with their ends in contact, usually three meeting at such an angle as to form the typical hexagonal meshes. They have a somewhat thick wall, and inside a layer of protoplasm, in which the green chlorophyll is diffused, not collected into definite chloroplasts as usual in algae. The centre is filled with cell sap. The protoplasm contains numerous and quite typical pyrenoids each consisting of a central body with a layer of starch-grains outside. These may be considered as food reserve. At the commencement of reproduction they disappear, and are obviously used up. There is also fine-grained starch in the protoplasm, used for the purposes of life and growth. Many nuclei are present in each cell. The net is born with a certain number of cells, and always continues the same; if, owing to injury, a part is destroyed, it is not replaced. A small, complete net, consisting, it may be, of some thousands of cells, is formed inside each of the members of the original net. The mother cell-wall gelatinises, and the young one is set free. What causes the ap-

pearance or disappearance of Hydrodictyon is not understood. After being very plentiful it will totally disappear perhaps for several years, and then there is a sudden reappearance. These outbreaks are known in some parts as the "breaking of the meres." For instance, Hydrodictyon appeared formerly in the lake in Kew Gardens. Mr. Burton has looked for it for more than thirty years there, and only found one very small specimen up to last autumn, when a tremendous outbreak occurred. In less than four weeks, however, it had all disappeared. He suggested that the probable explanation was a combination of several favourable circumstances which do not frequently arise, possibly some special type of weather and some narrow range of temperature at a particular season.

Mr. F. J. Perks (Hon. Treasurer) read some Notes by Mr. E. M. Nelson on various insect structures. The wing of the Neuropteron, *Agrion pulchellum*, he pointed out, is a very interesting microscopical object. The membrane is double, bordered by a rim edged with saw-like teeth, the surface is divided by nervures which are peculiar—the transverse bars, as well as four longitudinal, have on one edge thorns, and on the other saw-like teeth; three other longitudinal ribs have saw-teeth on one edge and fine teeth on the other, but no thorns. At one part on the edge of the wing is a dark-coloured compartment improperly called "stigma." This is really a pocket, and is obviously used for producing a sound. If the border of the wing is examined through a half-inch objective and a ×10 eyepiece, a delicate hair can be seen between the teeth of the saw, very minute, the largest found measuring 23 μ in length and 2 μ in breadth. They spring out of circular rings, as do most insect hairs, but not like those on the membrane of a blowfly's tongue, which have no rings. Mr. Nelson points out that careful examination of the small hairs on the wing of a wasp will show they are twisted like the tusk of a narwhal. The hairs on a bee's wing are similar, but not so twisted, while they have no ring. Those on the wing of a saw-fly issue from a boss. The hairs on the ovipositor of Phalangia have a ringed base, and on the last two terminal stripes, where the hairs are larger, the ringed boss has a circle of minute hairs. The hair itself is tubular, has a filamentous end, and at the side there is a minute prong. At the end of each of the two lobes of the ovipositor

is a small boss covered with minute hairs, without ring bases, and bluntened, probably open; they have internal ring (not spiral) structure similar to an artery. The examination of the mandibles of a gadfly, *Tabanus bovinus*, will show the most wonderful saw in the world, having 10,000 to 16,000 teeth per inch on one edge, while the other is the keenest blade in existence. After describing the sting of a hornet, *Vespa crabro*, he draws attention to the pygidium of a flea. If the right- and left-hand edges are examined, a Eustachian tube will be seen. The apparatus corresponds to the drum of an ear, and must have an air-passage to equalise the pressure on either side. At the base of the haltere in a blowfly a similar tube is easily seen.

At the 509th Ordinary Meeting of the Club, held on June 22nd, 1915, the President, Professor Arthur Dendy, D.Sc., F.R.S., in the chair, the minutes of the meeting held on May 28th were read and confirmed.

Mr. Reginald Arthur Price was balloted for and duly elected a member of the Club.

The President stated that, as the first meeting to consider the formation of the Club was held on June 14th, 1865, the present meeting marked an epoch in the history of the Quekett Club, as it concluded the first fifty years of work, and all who knew would agree that it had been to them a half-century full of important results, and that the present condition of the Club was very satisfactory. Most of the members present knew that the Committee had begun to arrange for the celebration of this event, but they had since thought it necessary to abandon the idea, as it was felt that any kind of rejoicing would be out of harmony with the prevailing feeling at the present time, and he thought they would all be agreed that the most dignified thing they could do under the circumstances was to defer that celebration. He wished also in the first place to say that the Hon. Editor had inserted in the last number of the Journal a very interesting account of the early history of the Club, which would no doubt be read with great pleasure by the members. Another point was that they had the pleasure of seeing that evening present at their meeting three of the original members of the Club—Mr. R. T. Lewis, who had acted as their Honorary

Reporter from its commencement, Mr. Alpheus Smith, who was their Honorary Librarian for forty years, and Mr. Thomas Powell, whom they all had the pleasure recently of congratulating upon the attainment of his eightieth birthady. He hoped they would long be able to attend the meetings of the Club.

Dr. John W. Evans, of the Geological Department of the Imperial College of Science, South Kensington, then gave a lecture on "The Microscopical Examination of Minerals."

Dr. Evans stated that for many reasons a stationary stage and revolving nicols are most convenient, but add greatly to expense, and he found high-power objectives of great use for special examinations. Tube and eyepiece must be provided with a slot, so that a quartz wedge, gypsum plate, or eyepiece micrometer may be inserted in the focus of the eyepiece. This slot should be placed in a diagonal position, and not, like in many foreign instruments, from left to right, which makes special wedges and plates necessary. A good rock slice should range between 20 and 30 microns in thickness, but with transparent minerals much thicker sections may be usefully employed. For examination the section should be brought into the centre of the field, so that it lies beneath the intersection of the crossed wires, and the stage rotated until the index reading is zero. If with both nicols in the crossed position and the stage rotated the crystal section remain dark through a complete rotation, it is either isotropic or cut at right angles to the optic axis of a uniaxial crystal. If it continue uniformly faintly illuminated, it is at right angles to an optic axis of a biaxial crystal. Usually it will be dark at four points in the rotation when the directions of vibration of light traversing the crystal section are parallel to those of the nicols. These four points are known as "extinctions."

There is usually some difficulty in determining the position of maximum darkness corresponding to the true position of extinction, and one of the simplest of many methods is to rotate the stage towards the position of extinction alternately from opposite directions and to note the readings on each side where the same degree of obscuration has been obtained. The mean of several pairs of observations will give approximately the true position.

Ascertain which of the extinctions or directions of vibration

in the crystal section is the direction of vibration of light with the greater velocity, and which that of light with the less velocity, and determine, at the same time, the relative retardation, or, in other words, how far the slower moving vibrations have lagged behind the faster. (This is usually measured in micro-millimetres, or millionths of a millimetre.) For the purpose of making these determinations we insert both nicols in the cross position and rotate the stage till the direction of vibration is diagonal to those of the nicols. The two vibrations which pass the lower nicol are now resolved along the two directions of vibration of the section. If there were no relative retardation they would in emergence recombine to form a vibration parallel to the same direction as before, and would be extinguished by the upper nicol. As a result of the relative retardation, however, the various colours of the spectrum are transmitted in different degrees, so that the compound tints known as interference colours are obtained. These are dependent upon the amount of it, which is usually about the same for all colours of the spectrum.

Interference colours commence with complete darkness at zero relative retardation and pass through grey, white, yellow, orange and red, which last is seen when the relative retardation reaches 550 micro-m.m. These constitute the colours of the first order. Then follow purple, violet, blue, green, yellow and red up to a relative retardation of 1,000. These are the second order. Every addition of 550 micro-m.m. corresponds to another order with a similar succession of colours, gradually becoming more complex until they are delicate shades of green and pink, and with a relative retardation of about 4,000 micro-m.m. they slowly pass into white light.

If one nicol be rotated through a quarter turn so that the directions of vibrations of the two nicols are parallel, the colours are seen to pass through brown, red and blue to the yellowish green, marking the end of the first order at 550. Then the second, and gradually the colours fade into white light, exactly as with crossed nicols.

The amount of relative retardation in a crystal section may be roughly estimated directly from the interference colours between crossed and parallel nicols by comparison with tables or lithographic plates of colours giving the corresponding

relative retardations (one was exhibited at the lecture), but in determining colours so much depends upon the idiosyncrasy of the observer, and the character of the light, that results can only be relied on within very wide limits. In the smoky atmosphere of a London winter, for instance, the blue of the second order appears to pass into greenish yellow without any definite green intervening. Relative retardation is equal to the product of the thickness of the section and the birefringence, which is the relative retardation in a unit of distance, and is equal to the difference between the refractive indices of the two directions of vibration. In the case of a section of quartz 21 microns thick, cut parallel to the optic axis, the indices of refraction are 1·544 and 1·553, and the bi-refringence therefore 0·009. Accordingly the relative retardation $= 21 \times 0{\cdot}009 = 0{\cdot}189$ of a micron. For the purposes of determining the character of extinctions and the amount of relative retardation a quartz wedge or mica ladder may be employed.

Dr. F. E. Wright, of the Smithsonian Institute, Philadelphia, devised a combination of quartz wedge and gypsum, and Dr. Evans has successfully employed the same idea.

A quartz wedge is superposed on a gypsum plate, both being constructed with the usual orientation, so as to leave beyond the thin end of the wedge a square of gypsum, which may be used as an ordinary gypsum plate. The quartz will show a black band where it neutralises the gypsum. The point is marked zero. Every hundred micro-m.m. of relative retardation is shown either way. If the direction of the crystal section parallel to the slot be fast, the band will move towards the thick end of the wedge; if slow, towards the thin end.

The mica ladder consists of a succession of narrow cleavage plates of muscovite, with their length cut parallel to the trace of the optic axial plane, and therefore slow. Each strip should have a relative retardation of 100 micro-m.m. They are of different lengths and superposed to form a succession of steps each large enough to cover the whole cone of light in the lower slot, where they are usually employed, though useful in the focus of the eyepiece, if the upper nicol be placed above them. In either case they show a discontinuous series of colours corresponding to differences of 100 micro-m.m. If inserted over a section it is easy to show whether the two show additive or

subtractive relations. In the former case the stage should be rotated till the fast direction of the section is parallel to the slot. It may happen, then, that the section is neutralised by one of the steps, and therefore is of the same relative retardation. If one step just fails to neutralise and the next higher will more than do so, and neither are completely dark, then if they be equally bright, the relative retardation must be midway between ; if one is darker, then it will be proportionately nearer to that step. In this way the relative retardation can be estimated to within 20 or 30 micro-m.m. When the directions-image—*i.e.* the object viewed without an eyepiece reflected on the back lens of the objective—is examined between crossed nicols, it shows in the centre of the field the same interference colours as that seen in the object image. The colours move with the stage as it rotates without suffering any changes of configuration. At the same time the field is traversed by dark bands or brushes, which constitute the isogyre. As the rotation proceeds, these change both their position and their shape and may from time to time leave the field altogether. When the stage is in the position corresponding to extinction in the object-image or, in other words, when the vibrations in the section are parallel to the cross wires, the isogyre passes through the centre of the field and is known as a "central isogyre."

Dr. Evans concluded his lecture by describing the technical indications of the different isogyres.

The lecture was fully illustrated by diagrams and coloured lantern slides, which were, Dr. Evans pointed out, mostly due to the art of Mr. C. H. Caffyn.

There was a collection of photographs of rock sections on Lumière Autochrome plates, exhibited by Messrs. J. W. Ogilvy and C. H. Caffyn, and also a series of exhibits showing the process of mounting a rock section.

OBITUARY NOTICE.

EDWARD ALFRED MINCHIN, M.A., F.R.S.

(*Born February 26th*, 1866; *died September 30th*, 1915.)

The members of the Quekett Microscopical Club will have heard with the deepest regret the sad news of the death of our former President, Professor E. A. Minchin, M.A., F.R.S., which took place on September 30th at Selsey, at the comparatively early age of forty-nine.

Professor Minchin was one of the most distinguished men of science who have ever occupied the presidential chair of this Club, and his stimulating addresses will long be remembered by those of us who were privileged to hear them, while the kindly courtesy with which he was always ready to share his unrivalled knowledge of his special subjects endeared him to all his fellow-workers. It is to Professor Minchin that I owe my own introduction to the Club, and it may interest my fellow-members to hear of the cordial appreciation with which he spoke to me of the Club and its work. It was quite evident that he derived a very real satisfaction from his association with its members.

The Quekett Club, however, formed but a small part of the field in which Professor Minchin exercised his scientific activities. Both as a teacher and as an original investigator of the first rank, he was well known to zoologists in all parts of the civilised world. His luminous general treatises, especially those on the Sponges and the Protozoa, are landmarks in the progress of zoological science, while at the same time his own researches have broken new ground in many directions.

He was, I think, the most conscientious investigator that I have ever had the good fortune to meet. In the study of Spongology in particular he introduced a standard of painstaking accuracy that was sorely needed, and set an example of thoroughness that will be hard indeed for those who follow him to emulate. His most striking and important contributions to this department of zoology are his beautiful researches on the histology

and embryology of the Calcarea, especially those dealing with the origin and development of the triradiate spicules, or, rather, spicule-systems, as he showed them to be. The conclusions at which he arrived as the result of these investigations were of a startling and wholly unexpected nature. His most important memoirs on Sponges were produced while he occupied the chair of Zoology at University College, London, and it was, I know, no small grief to him to have to abandon these researches, at any rate to a large extent, when he accepted the newly created chair of Protozoology in the University of London and transferred his headquarters to the Lister Institute of Preventive Medicine at Chelsea.

While at University College he had already won a great reputation as a student of the Sporozoa, a group of Protozoa which in recent years has assumed such immense importance from the medical standpoint, and at the Lister Institute the parasitic Protozoa necessarily claimed his chief attention. Here his wonderful mastery of microscopical technique stood him in good stead, and his exquisitely illustrated memoirs on the Trypanosomes, published in *The Quarterly Journal of Microscopical Science*, would alone form a lasting monument to his industry and skill. His work in this direction took him far afield, for even before he resigned his chair at University College he had visited Uganda as a member of the Royal Society's Commission on Sleeping Sickness. His *Introduction to the Study of the Protozoa*, with special reference to the parasitic forms, published in 1912, will long remain the standard treatise on this most important subject.

The amount of hard work that Minchin managed to get through is marvellous. In spite of his delicate health and his preoccupation with original research of the most intricate and difficult character, and in addition to his numerous duties as a teaching professor, he managed to find time to take an active part in the work of scientific societies. His zeal and energy as President of the Quekett Microscopical Club are fresh in the memories of all of us, but he was also a Vice-President of the Zoological Society and latterly Zoological Secretary of the Linnean Society.

Minchin's last contribution to science was his Presidential Address to the Zoological Section of the British Association at Manchester, in September last. Those of us who were present on that occasion knew that the end was not far off, and it was with

sad feelings that we listened to his friend Mr. Heron-Allen, whom Minchin had chosen to read the address on his behalf. In this address the departing master summed up his views on that fascinating subject, the evolution of the cell, and showed us, what indeed we all knew before, that he was not only a specialist of the highest type, but gifted with a deep insight into the fundamental problems of his beloved science.

A. D.

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Jan. 24, 1868. Arthur Mead Edwards, M.D.
423, *Fourth Avenue, Newark, New Jersey, U.S.A.*

Feb. 17, 1893. Robert Braithwaite, M.D., F.L.S., F.R.M.S. (*Past President*)
26, *Endymion Road, Brixton Hill, S.W.*

Feb. 17, 1893. M. C. Cooke, M.A., LL.D., A.L.S. (*Past President*)
38, *Lindley Avenue, East Southsea, Hants.*

Feb. 17, 1893. T. Charters White, M.R.C.S., L.D.S., F.R.M.S. (*Past President*)
49, *Victoria Road South, Southsea.*

Mar. 19, 1897. B. T. Lowne, M.D., F.R.C.S., F.L.S. (*Past President*)
91, *Carlisle Road, Hove, Sussex.*

May 18, 1906. Dr. Eugène Penard
Rue Töpffer 3, *Geneva.*

Jan. 23, 1912. Alpheus Smith
14, *Leigham Vale, Streatham, S.W.*

April 23, 1912. Fred Enock, F.L.S., F.R.M.S., F.E.S.
13, *Tufnell Park Road, Holloway, N.*

LIST OF MEMBERS.

Date of Election.

Feb. 16, 1906. Abson, Herbert
14, *Gainsborough Road, Mile End, E.*

Dec. 23, 1913. Ainslie, Maurice Anderson, R.N., B.A., F.R.A.S.
8, *Woodville Road, Blackheath St.*

Feb. 16, 1906. Akehurst, Sydney Charles, F.R.M.S. (*Hon. Librarian*)
60, *Bowes Road, Palmer's Green, N.*

Feb. 19, 1904. Allardice, Lieut. William McDiarmid
Tregenna Longcross, St. Endellion North, Cornwall.

May 24, 1910. Allen, William Nassau
"*Caerneagh,*" *North Circular Road, Dublin.*

Jan. 28, 1913. Allison, Arthur Morris
8, *Sidney Road, Beckenham.*

Dec. 15, 1899. Angus, H. F., F.R.M.S.
83, *Wigmore Street, Cavendish Square, W.*

Mar. 24, 1914. Anthes, Ernst Hermann
21, *Lancaster Road, Hampstead, N.W.*

Feb. 25, 1913. Armitage, John Joseph, L.D.S.E.
5, *Cavendish Place, W.*

June 21, 1907. Arpin, John Edward
131, *Castelnau, Barnes, S.W.*

Feb. 22, 1889. Ashe, A., F.R.M.S.
55, *Warrior Square, Southend-on-Sea.*

Feb. 28, 1911. Austin, Henry
Tudor House, 120, *Greenwich Road, Greenwich, S.E.*

Date of Election.

June 4, 1909. Baddeley, William H. L.
29, *Church Crescent, Church End, Finchley, N.*

April 17, 1903. Bagshaw, Walter, J.P., F.R.M.S.
"*Moorfield,*" *Birkenshaw, near Bradford, Yorks.*

Sept. 26, 1884. Baker, F. W. Watson, F.R.M.S.
313, *High Holborn, W.C.*

Mar. 16, 1906. Baker, Henry James
13, *Moorgate Street, E.C.*

April 2, 1909. Baker, Wilfred E. Watson
313, *High Holborn, W.C.*

Nov. 25, 1913. Bale, Wm. Urontier, F.R.M.S.
63, *Walpole Street, Kew, Victoria, Australia.*

June 19, 1908. Banham, Edward Elliott
128, *Uxbridge Road, West Ealing, W.*

May 28, 1912. Barnard, Edward Jas.
10, *Denver Road, Stamford Hill, N.*

Feb. 25, 1913. Barnard, Joseph Edwin, F.R.M.S.
Park View, Brondesbury Park, N.W.

Mar. 19, 1886. Barnes, W.
23, *Jackson Road, Holloway, N.*

May 28, 1912. Barratt, Kenneth Franklin
"*Bell Moor,*" *Hampstead Heath, N.W.*

May 28, 1912. Barratt, Thos. Franklin
"*Bell Moor,*" *Hampstead Heath, N.W.*

Sept. 27, 1872. Bartlett, Edward, L.D.S., M.R.C.S.E.
38, *Connaught Square, W.*

Nov. 26, 1912. Bassett, Ernest Henry
"*Pro tem,*" *Amberley Road, Palmer's Green, N.*

June 17, 1892. Bates, C.
1, *Windsor Road, Denmark Hill, S.E.*

Oct. 18, 1895. Baugh, J. H. A.
63, *Bambridge Road, Hammersmith, W.*

June 4, 1909. Baxendale, Frederick G.
22, *Holmesdale Avenue, East Sheen.*

Jan. 16, 1891. Baxter, W. E., F.R.M.S.
170, *Church Street, Stoke Newington, N.*

Date of Election.	
June 19, 1908.	Bayliffe, John H.
Nov. 26, 1875.	Beaulah, John *Albert House, Brigg.*
July 25, 1884.	Beck, C., F.R.M.S. 68, *Cornhill, E.C.*
Nov. 26, 1912.	Bellamy, Geo. Claxson 16, *Great Ormond Street, W.C.*
June 27, 1911.	Bennett, Lionel C. 49, *Erpingham Road, Putney, S.W.*
Feb. 16, 1906.	Bestow, Charles H., F.R.M.S. 43, *Upper Clapton Road, N.E.*
June 16, 1905.	Blair, William Nisbet 23, *West Hill, Highgate, N.*
Oct. 2, 1908.	Blockley, Edgar A. 26, *Mayfield Avenue, Chiswick, W.*
May 19, 1899.	Blood, Maurice, M.A., F.C.S., F.R.M.S. 8, *Chichele Road, Cricklewood, N.W.*
Feb. 25, 1913.	Booker, Alfred James 37, *Claremont Road, Highgate, N.*
April 25, 1911.	Bowtell, Alexander Jas. 123, *Dalston Lane, N.E.*
Nov. 15, 1907.	Bradford, William Barnes 65, *Tyrwhitt Road, St. John's, S.E.*
Nov. 17, 1905.	Bremner, John Unthank 277, *King Street, Hammersmith, W.*
Jan. 24, 1911.	Bridge, Samuel 28, *Larkhall Rise, Clapham, S.W.*
Nov. 6, 1908.	Broad, John Moxon 2, *Nicoll Road, Harlesden, N.W.*
May 28, 1912.	Brooke, Thos. Robinson 12, *Warren Road, Chingford, N.E.*
Dec. 4, 1908.	Brooks, Theodore, F.R.M.S. *British Vice-Consul, Guantanamo, Cuba.*
Dec. 19, 1890.	Brough, J. R. *"Eversley," Shepherd's Hill, Highgate, N.*
Mar. 15, 1907.	Browett, William *"Beaumont," Pearfield Road, Forest Hill, S.E.*
May 24, 1910.	Brown, Edward George 8, *Freke Road, Battersea, S.W.*

Date of Election.

Jan. 18, 1907. Brown, Nicholas Edward, A.L.S.
6, *The Avenue, Kew.*

Jan. 28, 1887. Browne, E. T., M.A., F.R.M.S.
Anglefield, Berkhamsted, Herts.

Mar. 18, 1904. Brushfield, N. W.
13, *Allfarthing Lane, Wandsworth Common, S.W.*

Jan. 15, 1892. Bryce, David
37, *Brooke Road, Stoke Newington, N.*

May 28, 1912. Bull, Albert Edwd.
3, *Canterbury Terrace, Sudbury, Harrow.*

May 23, 1911. Bunnin, Charles A.
113, *Newlands Park, Sydenham, S.E.*

May 15, 1908. Bunting, Percival J.
"*Lyndhurst,*" *Birches Barn Road, Wolverhampton.*

Jan. 20, 1905. Burnell, Charles Edward
29, *High Street, Shepton Mallet.*

Feb. 28, 1913. Burns, Dr. Nesbitt, M.B., B.A., F.R.S.E.
"*The Lodge,*" *Highbridge, Somerset.*

April 20, 1906. Burrell, T. Leonard
20, *Upper Hornsey Rise, Islington, N.*

Feb. 19, 1904. Burton, James (*Hon. Sec.*),
8, *Somali Road, West Hampstead, N.W.*

Jan. 24, 1911. Butcher, Thomas William, M.B., C.M., F.R.M.S.
3, *Clifton Street, Blackpool.*

Feb. 19, 1904. Butterworth, Arthur Cyrus, F.R.M.S.
Glanville, Crowstone Road, Westcliff-on-Sea.

April 15, 1904. Caffyn, Charles Henry,
32, *Falkland Road, Hornsey, N.*

June 18, 1897. Campbell, Colney
47, *Selborne Road, Southgate, N.*

Mar. 16, 1906. Capell, Bruce John, F.R.M.S.
10, *Castelnau, Barnes, S.W.*

Mar. 28, 1914. Carlile, E.
28, *Chatsworth Road, Croydon.*

Date of Election.

Jan. 20, 1905. Carrington, John
P.O. Box 48, East London, South Africa.

May 24, 1910. Carruthers, Ferdinand Gilbert
10, *Addison Road, Bedford Park, W.*

Jan. 25, 1910. Carter, John Arthur
6, *Temple Road, Stowmarket.*

June 17, 1892. Chaloner, G., F.C.S.
South Street, Colyton, S.O., Axminster.

Mar. 17, 1905. Chapman, David Leighton
100, *Tooley Street, S.E.*

June 28, 1910. Charlton, Alfred Edward
13, *Parkhurst Road, Camden Road, N.*

Oct. 26, 1909. Cheavin, Harold Squire, F.R.M.S.
70, *Somerset Road, Huddersfield.*

April 22, 1913. Cheshire, Frederic John, F.R.M.S.
23, *Carson Road, Dulwich, S.E.*

Mar. 22, 1878. Chester, The Very Rev. the Dean of
The Deanery, Chester.

Dec. 18, 1896. Chipps, F. W.
201, *Castelnau, Barnes, S.W.*

Jan. 20, 1905. Christie, John, F.R.M.S.
Henleigh, Kingston Hill, Surrey.

May 18, 1906. Churchouse, G.
30, *Natal Road, Bowes Park, N.*

Mar. 17, 1905. Clemence, Walter
Farringford, Walton-on-Thames.

Jan. 27, 1914. Clibborn, Lt.-Col. John
87, *Victoria Street, S.W.*

Oct. 18, 1907. Coldwells, William Henry
Redcote, Shirley Road, Wallington.

Jan. 28, 1913. Coles, Alfred C., M.D., D.Sc., F.R.S.E.
"*York House*," *Poole Road, Bournemouth.*

Mar. 5, 1909. Collier, Oswald
The Hermitage, Snaresbrook.

Nov. 16, 1906. Collins, Brenton Robie, M.A.
Gorsebrook, Tunbridge Wells, Kent.

Oct. 21, 1904. Conrady, Alexander Eugen, F.R.A.S.
23, *Fanchford Road, Stamford Brook, W.*

Date of Election.

Mar. 25, 1913. Cook, John Thomas
106, *Thurlow Park Road, Dulwich, S.E.*

Nov. 26, 1912. Coon, Joseph May
"*Morwenna*," *St. Austell.*

April 20, 1906. Couch, Robert Percy

Jan. 18, 1901. Cox, Thomas N.
104, *Tressillian Road, Brockley, S.E.*

Jan. 15, 1904. Cox, William
"*The Pound*," *Lingfield, Surrey.*

June 19, 1903. Coxhead, G. W.
5A, *Springfield Gardens, Upper Clapton, N.E.*

Jan. 25, 1910. Crabtree, James Fox, B.A.
40, *Brazennose Street, Manchester.*

Dec. 20, 1901. Craig, Thomas, F.R.M.S.
26, *Selkirk Avenue, Montreal, Canada.*

Nov. 25, 1913. Creese, Edward J. E., F.Z.S., F.R.M.S.
29, *Cornford Grove, Balham, S.W.*

Nov. 21, 1902. Cressey, Dr. G. H.
Oak Manor, Tonbridge.

Aug. 28, 1868. Crisp, Sir Frank, LL.B., V.P.L.S., B.A., F.R.M.S., F.G.S., F.Z.S.,
5, *Lansdowne Road, Notting Hill, W.*

Mar. 20, 1908. Croger, Frank Clifford
114, *Wood Street, E.C.*

Nov. 16, 1906. Crosbie, Walter
Kenilworth, Lyonsdown Avenue, New Barnet.

Jan. 25, 1910. Cross, Edward

Feb. 16, 1900. Crossland, R. E., A.R.I.B.A.
10, *Serjeant's Inn, Fleet Street, E.C.*

Mar. 16, 1894. Culshaw, Rev. George H., M.A.
The Rectory, Iver Heath, Bucks.

June 25, 1880. Curties, C. Lees, F.R.M.S.
244, *High Holborn, W.C.*

Jan. 16, 1903. Curties, C. L., jun.
244, *High Holborn, W.C.*

May 18, 1906. Cuzner, Edgar, F.R.M.S.
36, *Trothy Road, Bermondsey, S.E.*

Date of Election.

Nov. 18, 1904. Dade, Willoughby Dreyer
13, *Glendinning Avenue, Weymouth.*

Jan. 17, 1908. Dallas, Charles Caldwell, F.R.G.S., F.Z.S.
Eastley Wootton, New Milton, Hants.

Dec. 21, 1906. Darlaston, Herbert William Hutton
31, *Freer Road, Birchfield, Birmingham.*

Feb. 28, 1911. Davidson, John
29, *Federation Road, Abbey Wood, Kent.*

Nov. 22, 1910. Davidson, Rev. Martin, M.A., B.Sc., F.R.A.S.
56, *Hudson's Road, Canning Town, E.*

June 16, 1905. Davies, Daniel, F.R.M.S.
12, *Eliot Hill, Blackheath, S.E.*

April 28, 1911. Davies, Daniel Arthur
12, *Eliot Hill, Blackheath, S.E.*

Jan. 19, 1906. Davies, Perceval Eckton
Abbeydale, Marmora, Road, Honor Oak, S.E.

June 24, 1913. Dean, Frank
1, *Langham Street, Portland Place, W.*

May 17, 1901. Deeley, George P.
Moushall, Amblecote, Brierley Hill, Staffordshire.

April 19, 1895. Delcomyn, Theo. A., F.R.M.S.
"Feldheim," Wimbledon Common, S.W.

Jan. 23, 1912. Dendy, Arthur, D.Sc., F.R.S. (*President*)
Vale Lodge, Hampstead Heath, N.W.

Nov. 17, 1893. Dennis, A. W.
56, *Romney Buildings, Milbank, S.W.*

Mar. 22, 1889. Dick, J.
Milber, Victoria Road, Mill Hill, N.W.

Feb. 15, 1907. Dilks, Arthur Charles, B.Sc.
Tardebigge, Bromsgrove.

June 24, 1913. Dinn, Harold H.
72, *Elmwood Road, Herne Hill, S.E.*

June 4, 1909. Dixon, Arthur L.
35, *North Hill, Highgate, N.*

June 17, 1892. Dixon-Nuttall, F. R., F.R.M.S.
"Ingleholme," Eccleston Park, near Prescot, Lancashire.

Date of Election.

Nov. 25, 1913. Dobell, Henry
74, *Babbacombe Road, Bromley, Kent.*

Feb. 22, 1910. Doughten, William S.
415, *Race Street, Philadelphia, Pa., U.S.A.*

Oct. 25, 1910. Douglas, William
Grafton House, Berkhamsted, Herts.

Oct. 24, 1911. Downing, Owen Walter
23, *Glenhouse Road, Eltham, Kent.*

Mar. 17, 1899. Downs, Arthur
2, *Ulverston Road, Walthamstow, E.*

Nov. 23, 1909. Draper, Bernard M.
9, *Pitt Street, Kensington, W.*

May 17, 1907. Drinkwater, Jesse, F.R.M.S.
St. Margaret's, Stanley Gardens, Wallington.

Nov. 15, 1901. Druett, C. R.
330, *Uxbridge Road, W.*

Dec. 28, 1909. Dumat, Frank C.

Feb. 22, 1910. Dunstall, George Kirkman, F.R.M.S.
82, *Darenth Road, Stamford Hill, N.*

Feb. 25, 1913. Durrad, John Wm., F.R.A.S.
350, *Fosse Road North, Leicester.*

June 19, 1891. Earland, Arthur, F.R.M.S.
34, *Granville Road, Watford.*

May 15, 1908. East, John Holtham
75, *Moorland Road, Weston-super-Mare.*

Sept. 25, 1868. Eddy, J. R., F.R.M.S., F.G.S.
The Grange, Carleton, Skipton, Yorkshire.

April 22, 1913. Edwards, Henry
22, *Carnarvon Road, Reading.*

Oct. 22, 1912. Edwardes, Seabury
Pegu, Lower Burma.

Feb. 21, 1902. Edwards, Thomas Jarvis
9, *St. Lawrence Road, Brixton, S.W.*

Oct. 22, 1912. Elliott, Wm.
97, *Devonport Road, Shepherd's Bush, W.*

Date of Election.	
Mar. 22, 1910.	Ellis, William Neale *The "Pharmacy," Appledore, Devon.*
Nov. 28, 1911.	Emsley, Harold Percy 31, *Victoria Road, Wood Green, N.*
Mar. 24, 1914.	Engelhardt, Conrad Wm. 6, *Shaftesbury Villas, Kensington, W.*
Feb. 28, 1879.	Epps, Hahnemann 95, *Upper Tulse Hill, Brixton, S.W.*
Dec. 20, 1907.	Evans, Benjamin 162, *Battersea Bridge Road, S.W.*
Nov. 17, 1905.	Evans, Morris B. 33, *Lady Margaret Road, Southall, Middlesex.*
Dec. 21, 1906.	Fawcett, Henry Hargreave *Thorncombe, near Chard, Somerset.*
June 24, 1913.	Fendich, Ernest Alfred 22, *Finedon Road, Wellingborough, Northants.*
June 16, 1893.	Filer, Frank E. 35, *Dancroft Road, Herne Hill, S.E.*
Feb. 19, 1904.	Finlayson, Daniel "*Redfern,*" *Pellatt Grove, Wood Green, N.*
Feb. 24, 1914.	Finlayson, Raymond 22, *Pellatt Grove, Wood Green, N.*
June 19, 1908.	Flamank, Sydney W. *Church House, Dean's Yard, Westminster, S.W.*
Nov. 23, 1888.	Flood, W. C. 119, *Highbury Hill, N.*
Mar. 25, 1913.	Ford-Fone, W. Edwin 146, *Palmers Road, New Southgate.*
June 23, 1871.	Freeman, H. E. *Walcot, Limes Avenue, New Southgate, N.*
Dec. 16, 1898.	French, Archibald J. 57, *Ermine Road, Lewisham, S.E.*
Jan. 18, 1907.	Fuelling, George Ernest 195, *High Road, Streatham, S.W.*
Feb. 22, 1910.	Fuller, Frederick Charles 9, *Goldington Road, Bedford.*

Date of Election.

Nov. 21, 1902. Fuller, William
24, *Coleford Road, Alma Road, Wandsworth, S.W.*

May 15, 1903. Gabb, G. H., F.C.S.
83, *Crayford Road, Tufnell Park, N.*

Nov. 25, 1913. Gamman, Robt.
13, *Park Road, High Barnet.*

Feb. 27, 1912. Gammon, Geo. Edwd.
6, *Mackintosh Place, Roath, Cardiff.*

Dec. 15, 1905. Gardner, Edward Lewis
1, *Craven Road, Harlesden, N.W.*

Jan. 20, 1899. Gardner, William, F.R.M.S.
292, *Holloway Road, N.*

Dec. 16, 1904. Garnett, Theodore, M.A. Oxon
South Bank, Grassendale, Liverpool.

Jan. 27, 1914. Gee, Harry Arthur
20, *Bucklersbury, E.C.*

Mar. 24, 1914. Gingell, Leonard Ralph
10, *Moring Road, Tooting, S.W.*

May 17, 1901. Gladding, Harold

Nov. 22, 1910. Gladstone, Reginald J., M.D.
22, *Regent's Park Terrace, N.W.*

Mar. 22, 1910. Gonville, Cyril H. K.
"*Milton,*" *Queen's Road, Buckhurst Hill, N.*

Feb. 24, 1914. Gooding, Alfred Charles
53, *Park Road, Battersea, S.W.*

Dec. 28, 1909. Gooding, Henry Cornish
Stowmarket, Suffolk.

April 2, 1909. Gordon, Fred William, F.R.M.S.
"*Graylands,*" *Augustus Road, Wimbledon Park, S.W.*

Feb. 22, 1910. Gordon, John W.
113, *Broadhurst Gardens, Hampstead, N.W.*

Nov. 15, 1907. Gray, W.
23, *Ramsden Road, Balham, S.W.*

Jan. 25, 1910. Green, Frederick N.
40, *Lombard Street, E.C.*

Date of Election.	
Jan. 16, 1903.	Green, H. O. 4, *Leamington Gardens, Seven Kings.*
Nov. 18, 1898.	Grocock, L. O.
May 24, 1910.	Grundy, James, F.R.M.S. "*Ruislip,*" *Teignmouth Road, Cricklewood, N.W.*
June 25, 1912.	Gurney, Joseph *Downs Farm, Pinner S.O., Middlesex.*
Feb. 19, 1904.	Gurney, Robert *Ingham Old Hall, Stalham, Norfolk.*
Nov. 28, 1911.	Guye, Dr. Paul 12, *Rue de Candolle, Geneva, Switzerland.*
Feb. 25, 1913.	Hall, Rd. 4, *Inglewood Mansions, West End Lane, Hampstead, N.W.*
Sept. 28, 1888.	Hall, T. F. 45, *Princes Gate, S.W.*
Feb. 22, 1910.	Hammond, Alfred Gauntlett 101, *Melody Road, Wandsworth, S.W.*
Jan. 25, 1910.	Hammond, Arthur Rashdall 15, *Genoa Road, Anerley, S.E.*
April 26, 1910.	Hammond, Leonard Frank 22, *Mercers Road, N.*
Oct. 22, 1886.	Hampton, W. *The Manor House, Weston, Staffordshire.*
Nov. 26, 1912.	Hardman, Wm., J.P. "*Fernleigh,*" *Bispham, near Blackpool.*
Nov. 22, 1910.	Harris, A. Wellesley, M.R.C.S., etc. "*Alnwick,*" *Berlin Road, Catford, S.E.*
May 19, 1905.	Harris, Charles Poulet, M.D., M.R.C.S., L.R.C.P., F.R.M.S. 98, *Lower Addiscombe Road, Croydon.*
Jan. 27, 1914.	Harris, Leslie Edwin 19, *Cheriton Square, Balham, S.W.*
Dec. 21, 1906.	Hasslacher, Charles John 3, *Kensington Park Gardens, W.*
Mar. 28, 1879.	Hawkins, C. E. 23, *Dalebury Road, Upper Tooting, S.W.*

Date of Election.

Nov. 26, 1912. Hayward, Leslie Chas.
68, *Queens Road, Bayswater, W.*

Feb. 15, 1901. Headley, F. W.
Haileybury College, Hertford.

Jan. 19, 1906. Heath, Charles Emanuel, F.R.M.S.
178, *Loughboro' Road, Brixton, S.W.*

Feb. 5, 1909. Hebdon, William
181, *Breakspears Road, Brockley, S.E.*

April 20, 1906. Herbert, Robert Henry
32, *Fairmead Road, Holloway, N.*

Feb. 21, 1908. Heron-Allen, Edward, F.L.S., F.G.S., F.R.M.S., F.R.Met.S., F.Z.S.
33, *Hamilton Terrace, N.W., and Large Acres, Selsey Bill, Sussex.*

Dec. 20, 1901. Hicks, Frederick H.
8, *Belmont Road, Wallington, Surrey.*

Dec. 22, 1910. Higginson, George Neale
42, *Bartholomew Road, Camden Town, N.W.*

Feb. 17, 1899. Hill, Edward J.
Darnlee, Melrose, N.B.

Nov. 26, 1912. Hill, Wm., F.G.S.
"*The Maples,*" *Hitchin.*

Nov. 15, 1895. Hilton, A. E.
1, *Highwood Avenue, North Finchley, N.*

May 15, 1908. Hiscott, Thomas Henry, F.R.M.S.
16, *Woodville Road, Ealing, W.*

May 27, 1913. Hoare, Stanley
"*Baronscourt,*" *The Bishops Avenue, N.*

Nov. 16, 1906. Hocking, William John
Royal Mint, E.

Dec. 15, 1893. Holder, J. T.
114, *Pepys Road, New Cross, S.E.*

Feb. 26, 1875. Holford, Christopher
5, *Northumberland Avenue, Upper Richmond Road, Putney, S.W.*

Dec. 20, 1907. Holmes, Frederick
217, *Franciscan Road, Tooting, S.W.*

Date of Election.	
June 25, 1912.	Hook, Gerald Francis 9, *Barrowgate Road, Chiswick, W.*
May 27, 1913.	Hook, Reginald Vincent 9, *Barrowgate Road, Chiswick, W.*
Jan. 15, 1904.	Hopkinson, John, F.L.S., F.G.S., F.R.M.S. *Weetwood, Watford.*
Oct. 26, 1866.	Horncastle, Henry *"Lindisaye," Woodham Road, Woking.*
April 15, 1898.	Hounsome, John 21, *Edith Road, Plashet Grove, East Ham, E.*
Dec. 4, 1908.	Howard, George *Sitwell Vale, Moorgate, Rotherham, Yorks.*
Oct. 19, 1894.	Howard, R. N., M.R.C.S., F.R.M.S. *The Cape Copper Co., Ookiep, Port Nolloth, Namaqualand, Cape Colony, South Africa.*
June 25, 1912.	Howorth, Geo. Franklin Wise 55, *Grovelands Road, Palmer's Green, N.*
Oct. 19, 1894.	Hughes, F. *Wallfield, Reigate.*
May 28, 1886.	Hughes, W. 32, *Heathland Road, Stoke Newington, N.*
Nov. 23, 1909.	Huish, Charles Henry, F.R.M.S. 23, *Champion Grove, Grove Lane, S.E.*
June 4, 1909.	Hunter, John E. *"Strathblane," Park Road, Wallington.*
Dec. 20, 1901.	Hurrell, Harry Edward 25, *Regent Street, Great Yarmouth.*
Feb. 25, 1913.	Hutchin, Chas. Duncan *c/o Meredith & Drew, Ltd., High Street, Shadwell, E.*
May 24, 1867.	Ingpen, J. E., F.R.M.S. 21, *Wrotham Road, Broadstairs.*
Feb. 16, 1906.	Inwards, Richard, F.R.A.S. 6, *Croftdown Road, Highgate Road, N.W.*
Feb. 28, 1911.	Jacob, Hugh Frederick Dawson, M.I.E.E. *c/o Jessop & Co., Ltd.*, 93, *Clive Street, Calcutta.*

Date of Election.

Feb. 27, 1912. Jacobs, Reginald
24, *Glenmore Road, Belsize Park, N.W.*

April 26, 1910. Jervis, Rev. Edward S.
St. Peter's Vicarage, Streatham, S.W.

Nov. 22, 1910. Jewell, Henry
152, *Leathwaite Road, Clapham Common, S.W.*

Nov. 17, 1905. Jones, Arthur Morley
11, *Eaton Rise, Ealing, W.*

April 26, 1910. Jones, George Fisher
Devonshire House, Osterley Park Road, Southall, W.

Jan. 18, 1907. Jones, Rev. Robert Francis
28, *Douglas Road, Canonbury, N.*

Feb. 22, 1910. Jones, William Llewellyn
Manley Knoll, Helsby, Cheshire.

Feb. 22, 1910. Joshua, Edward Cecil
St. James's Buildings, William Street, Melbourne, Victoria.

Nov. 17, 1905. Karleese, Benjamin
The Dell, Barnt Green, Worcestershire.

May 23, 1873. Karop, G. C., M.R.C.S., F.R.M.S., etc.
Inniscorig, Beltinge Road, Herne Bay.

Feb. 25, 1913. Kaufmann, James C., LL.D.
49, *Queen Street, Melbourne.*

June 21, 1907. Kemp, Francis H. N. C.
15, *Vernon Road, Hornsey, N.*

July 25, 1884. Kern, J. J.
63, *Queens Road, Beckenham, Kent.*

Nov. 18, 1904. Kew, H. Wallis
3, *Herndon Road, Wandsworth, S.W.*

May 17, 1901. Kirkman, Hon. Thomas, M.L.C., F.R.M.S.
Croftlands, Esperanza, Natal.

May 19, 1905. Kitchin, Joseph, F.R.M.S.
"*Ingleneuk,*" 14, *Brackley Road, Beckenham, Kent.*

Mar. 22, 1889. Klein, S. T., F.R.A.S., F.L.S., F.R.M.S.
"*Hatherlow,*" *Raglan Road, Reigate.*

Date of Election.

Dec. 28, 1909. Knox, Sydney W.
61, *Cambridge Street, Hyde Park, W.*

Mar. 24, 1914. Koch Victor, M.E.
43, *Elgin Avenue, Maida Vale, W.*

Feb. 17, 1905. Lambert, Charles Alexander
Bank of New South Wales, Warwick, Queensland.

Jan. 18, 1907. Larkin, Thomas Gaisford
29, *Thornlaw Road, West Norwood, S.E.*

Feb. 27, 1912. Laverach, Clyvie Cordukes
Broughton Rise, Malton, Yorks.

June 17, 1904. Lawrence, Frederick George
c/o Lionel Samson & Son, Cliff Street, Fremantle, West Australia.

Feb. 25, 1913. Lawrence, Harry John
7, *Norman Road, South Wimbledon, S.W.*

April 26, 1910. Lawrence, William John
21, *Cambridge Road, Lee, S.E.*

Mar. 16, 1900. Lawson, Peter
"*Jesmond,*" *Nella Road, Fulham Palace Road, S.W.*

Jan. 1, 1909. Leadbeater, Herbert C.
81, *Elborough Street, Southfields, S.W.*

Jan. 20, 1905. Lees, Rev. Frederick Clare,
45, *Cavendish Road, Sutton, Surrey.*

Nov. 21, 1902. Leonard, Edward
14, *Fairview Road, Oxton, Birkenhead.*

Nov. 17, 1905. Levett, Rev. Robert Kennedy, F.R.M.S.
The Junior School, Bradfield College, Reading, Berks.

Jan. 17, 1908. Levin, Arthur Everard
"*The Croft,*" *Bickley, Kent.*

Feb. 22, 1910. Lewis, Frederic Henry
"*Ashmore,*" *King's Avenue, Clapham Park, S.W.*

April 27, 1866. Lewis, R. T., F.R.M.S. (*Hon. Reporter*)
41, *The Park, Ealing, W.*

Nov. 25, 1913. Liddon, Capt. Matthew Robert
12, *Kensington Court, W.*

Date of Election.

June 26, 1868. Lindley, W. H., jun.
29, *Blittersdorffs Platz, Frankfort-on-Main.*

Mar. 24, 1914. Lloyd, Francis Wm.
85, *Gracechurch Street, E.C.*

Dec. 23, 1913. Lock, Thos. Benjn.
78, *Riggindale Road, Streatham, S.W.*

Jan. 18, 1907. Lyon, Massey, F.R.M.S.
c/o Messrs. Coutts, 440, *Strand, W.C.*

May 25, 1883. Mainland, G. E., F.R.M.S.
14, *The Norton, Tenby, South Wales.*

Nov. 26, 1912. Mardon, Daniel Arthur
"*Emscote,*" *Bishops Stortford.*

June 17, 1898. Marks, Kaufmann J., F.R.M.S.
4, *Woodchurch Road, West Hampstead, N.W.*

Jan. 24, 1911. Marsh, George Robertson, M.A.
Mallards Close, Twyford, near Winchester, Hants.

Feb. 15, 1895. Marshall, William John, F.R.M.S.
20, *Emlyn Road, Shepherd's Bush, W.*

May 18, 1906. Martin, William
"*Kethlen,*" *Burgh Heath, Epsom, Surrey.*

Nov. 28, 1911. Martin, Wm. Julius
55, *Breakspears Road, Brockley, S.E.*

Nov. 18, 1898. Massee, G., F.L.S.
Royal Gardens, Kew.

Jan. 28, 1913. Mavor, Hilary
"*Rookwood,*" *Ingatestone, Essex.*

Jan. 15, 1892. Maw, W. H., F.R.M.S., F.R.A.S.
18, *Addison Road, Kensington, W.*

Mar. 28, 1911. Maxwell, Edward Kelly, B.A.
H.M. Patent Office, W.C.

April 23, 1912. Mead, Arthur

May 19, 1893. Merlin, A. A. C. Eliot, F.R.M.S.
British Consulate, Volo, Greece.

Oct. 18, 1907. Mestayer, Richard L., M.I.C.E., F.R.M.S.
Lambton Quay, Wellington, New Zealand.

Date of Election.

Mar. 26, 1912. Metcalf, John
St. Bede's, Hermon Hill, Woodford, E.

July 27, 1877. Michael, A. D., F.L.S., F.Z.S., F.R.M.S.
The Warren, Studland, near Wareham, Dorset.

July 7, 1865. Millett, F. W., F.G.S., F.R.M.S.
Eniscoe, Brixham, Devon.

Feb. 25, 1913. Mills, Fdk. Wm., F.R.M.S.
Thornleigh Edgerton, Huddersfield.

Jan. 20, 1905. Milne, William
Uitenhage, Cape Colony, South Africa.

Oct. 18, 1907. Minchin, Edward Alfred, M.A., Ph.D., F.R.S., (*Vice-President*)
53, *Cheyne Court, Royal Hospital Road, Chelsea, S.W.*

Oct. 18, 1901. Moore, Harry, F.R.M.S.
12, *Whiston Grove, Moorgate, Rotherham, Yorks.*

July 26, 1878. Morland, Henry
Cranford, near Hounslow.

Oct. 25, 1910. Morris, Charles Barham
Waitaki Pharmacy, Thames Street, Oamaru, N.Z.

June 25, 1912. Morris, Jesse Crawford
Harrisville, Harrison County, Ohio, U.S.A.

June 4, 1909. Mortimer, Hugh Hamilton
20, *Birchin Lane, E.C.*

Jan. 16, 1891. Muiron, C.
49, *Chatsworth Road, Brondesbury, N.W.*

Dec. 23, 1913. Mumford, Frank Septimus
Belmont, Doncaster.

Nov. 22, 1910. Mummery, J. Howard, M.R.C.S.
Islips Manor, Northolt, Middlesex.

June 16, 1905. Myles, James Cellars
53, *Carlyle Road, Manor Park, S. Essex.*

Jan. 27, 1914. Nall, Rev. Geo. Herbert
18, *Deans Yard, Westminster, S.W.*

Mar. 24, 1876. Nelson, E. M., F.R.M.S.
Beckington, Bath.

Date of Election.

May 16, 1902. Nevill, Rev. T. J., F.R.M.S.
2, *Grange Road, Eastbourne.*

Feb. 15, 1907. Newman, Charles Arnold
Oundle, Northants.

May 27, 1913. Newmarch, Edgar Ribton
4, *The Drive, Walthamstow, N.E.*

Jan. 26, 1872. Newton, E. T., F.R.S., F.G.S.
Florence House, 13, *Willow Bridge Road, Canonbury, N.*

Jan. 17, 1908. Nicholson, Alfred
7, *Belton Road, Sidcup.*

Dec. 23, 1913. North, Jas. Herbert
11, *Parliament Hill, Hampstead, N.W.*

Nov. 28, 1911. Nutt, Hy. Francis
51, *Gurdon Road, Charlton, S.E.*

Feb. 25, 1913. Oatley, Wm.
Badcox, Frome

Feb. 16, 1900. O'Donohoe, T. A.
8, *Myrtle Road, Acton, W.*

Jan. 24, 1879. Offord, J. M., F.R.M.S.
3, *Cleveland Gardens, West Ealing, W.*

Dec. 22, 1876. Ogilvy, C. P., F.L.S.
Sizewell House, Leiston, near Saxmundham, Suffolk.

May 17, 1907. Ogilvy, J. Wilson, F.R.M.S.
18, *Bloomsbury Square, W.C.*

Nov. 15, 1907. Oke, Alfred William, B.A., LL.M.
32, *Denmark Villas, Hove.*

Nov. 18, 1892. Orfeur, Frank, F.R.M.S.
91, *Effra Road, Brixton, S.W.*

April 23, 1912. Owen, Wm. Hy.
19, *Home Park Road, Wimbledon.*

Dec. 27, 1867. Oxley, Frederick, F.R.M.S.
c/o A. E. Linton, Esq., Box 9, *P.O., Nairobi, British East Africa.*

Dec. 18, 1903. Oxley, F. J., M.R.C.S.
1, *Dock Street, E.*

Date of Election.

Feb. 27, 1912. Palmer, Hy., J.P., F.R.G.S.
Monks Holme, Corbridge-on-Tyne.

Nov. 25, 1913. Panichelli, Frank
7, *Rowan Road, Hammersmith, W.*

April 10, 1910. Parfitt, Edward William
7, *Gatcombe Road, Tufnell Park, N.*

Feb. 25, 1913. Parrott, Fdk. Wm.
The Downs, Bowden, Cheshire.

Oct. 27, 1871. Parsons, F. A., F.R.M.S.
15, *Osborne Road Finsbury Park, N.*

Dec. 16, 1904. Patterson, George
20, *Madrid Road, Castlenau, Barnes, S.W.*

July 23, 1886. Paul, R.
"*Holmbush,*" *Cyprus Road, Exmouth, Devon.*

Jan. 18, 1901. Paulson, Robert, F.L.S., F.R.M.S.
"*Glenroy,*" *Cecil Park, Pinner, Middlesex.*

May 24, 1867. Pearson, John
40, *Maida Vale, W.*

May 23, 1911. Pells, Cyril E.,

May 20, 1904. Perks, Frederick John (*Hon. Treasurer*)
48, *Grove Park, Denmark Hill, S.E.*

Jan. 18, 1907. Perry, Francis Gough
2, *The Cloisters, Gordon Square, W.C.*

Mar. 17, 1905. Phipps, William Joseph
132, *Pinner Road, Oxhey, Herts.*

Feb. 20, 1903. Pilcher, Charles Frederick

Nov. 15, 1895. Pillischer, J., F.R.M.S.
88, *New Bond Street, W.*

April 25, 1910. Pinchin, Ernest Alfred, B.Sc.,
4, *Gleneldon Road, Streatham, S.W.*

Nov. 26, 1912. Pitt, Edward
Madeley Ho., Gerrard's Cross, Bucks.

Nov. 19, 1897. Pittock, George Mayris, M.B., F.R.M.S.
Winton, Whitstable Road, Canterbury.

Jan. 15, 1904. Pledge, John H., F.R.M.S. (*Hon. Assistant Secretary*)
72, *Nibthwaite Road, Harrow.*

Date of Election.

Nov. 23, 1883. Plowman, T.
Nystuen Lodge, Bycullah Park, Enfield.

Sept. 21, 1894. Pollard, Jonathan, F.R.M.S.
10, *Porteus Road, Paddington Green, W.*

May 18, 1900. Poser, M., F.R.M.S.
37–38, *Hatton Garden, E.C.*

June 21, 1895. Poulter, Christopher S.
Mount Lodge, Parkhurst Road, Bexley, Kent.

Feb. 17, 1899. Powell, Arthur
28, *Stafford Terrace, Kensington, W.*

May 17, 1901. Powell, David, M.A., F.R.M.S.
Overstrand, Grove Park Road, Chiswick, W.

July 7, 1865. Powell, Thomas H., F.R.M.S.
Emsdale, Greenham Road, Muswell Hill, N.

Dec. 20, 1907. Pratt, John Edwin
6, *Heathfield Terrace, Seven Kings, Essex.*

June 4, 1909. Pring, S. W.
"*Sandhill,*" *Avondale Road, Newport, Isle of Wight.*

Nov. 26, 1912. Pulford, Herbert, M.A., etc.
The Winnats, Lowestoft Road, Gorleston-on-Sea.

Feb. 28, 1911. Pullman, John
The Knollsea, Lilliput, Dorset.

Nov. 6, 1908. Quick, Albert Hedley
"*Inverness,*" *Malvern Road, Thornton Heath.*

Jan. 18, 1901. Radley, Percy E., F.R.M.S.
30, *Foxgrove Road, Beckenham, Kent.*

Nov. 25, 1913. Ramsay, Ernest Wm.
14, *Whiteley Road, Upper Norwood, S.E.*

April 22, 1913. Rawson, Col. Herbert Edward, C.B.
Home Close, Heronsgate, Herts.

Nov. 16, 1906. Reid, Duncan J., M.B., C.M.
20, *Blakesley Avenue, Ealing.*

Mar. 20, 1896. Rheinberg, Julius, F.R.M.S.
23, *The Avenue, Brondesbury Park, N.W.*

Date of Election.

Sept. 18, 1891. Richards, F. W.
212, *Notre Dame Street West, Montreal, Canada.*

Oct. 2, 1908. Richards, William
3, *Favart Road, Fulham, S.W.*

Jan. 18, 1901. Richardson, John
28, *Beaumont Avenue, Richmond, Surrey.*

Nov. 6, 1908. Rink, Max
9, *Cannon Place, Christchurch, Hampstead, N.W.*

June 21, 1901. Robertson, Sir Helenus R., F.R.M.S.
Upton Grange, Chester.

Mar. 15, 1907. Robertson, James Alexander, F.R.M.S.
Lune View, Fleetwood.

April 28, 1914. Robotham Fras. Edward
48, *Lillieshall Road, Clapham, S.W.*

Nov. 16, 1900. Rogers, G. H. J., F.R.M.S.
55, *King Street, Maidstone.*

June 4, 1909. Rolph, Frank
Harts Stables, Woodford Green, E.

Jan. 25, 1884. Rosseter, T. B., F.R.M.S.
East Kent Club, Canterbury.

Jan. 26, 1883. Rousselet, Charles F. (*Vice-President and Hon. Secretary for Foreign Correspondence*), Curator R.M.S.
Fir Island, Mill Hill, N.W.

Nov. 26, 1912. Row, Rd. Wm. Harold
36, *Lexham Gardens, Kensington, S.W.*

Nov. 18, 1904. Rowley, Frederick Richard, F.R.M.S.
8, *Pinhoe Road, Heavitree, Exeter.*

April 27, 1888. Russell, J.
16, *Blacket Place, Newington, Edinburgh.*

Jan. 23, 1912. Ryan, Ernest K. W.
5, *Rossdale Road, Putney, S.W.*

Mar. 24, 1914. St. George, Harry A.
112, *Albany Street, Regent's Park, N.W.*

Nov. 21, 1902. Sanderson, R. Z.
26, *Baronsfield Road, St. Margaret's, E. Twickenham, Middlesex.*

Date of Election.

Dec. 23, 1913. Saunders, Reginald Arthur
10, *Regent's Park Road, N.W.*

April 2, 1909. Saxton, Thomas R., A.M.I.C.E., F.R.M.S.
43, *East Bank, Stamford Hill, N.*

Nov. 28, 1911. Schmerl, Augustus
34, *St. Gabriel's Road, Cricklewood, N.W.*

June 20, 1890. Scourfield, D. J., F.Z.S., F.R.M.S. (*Vice-President*)
63, *Queen's Road, Leytonstone, E.*

May 20, 1898. Sears, Robert S. W.
1, *Lisson Grove, N.W.*

Jan. 27, 1914. Shelley, G. H.
51, *Champion Grove, Denmark Hill, S.E.*

Nov. 25, 1913. Shepherd, Benjamin
Fir Cottage, Oak Lane, Bounds Green, N.

Dec. 28, 1909. Shephard, John
Clark Street, South Melbourne, Victoria.

May 26, 1876. Shepheard, Thomas, F.R.M.S.
Kingsley, Bournemouth West.

June 21, 1907. Sheppard, Alfred William, F.Z.S., F.R.M.S. (*Hon. Editor*)
1, *Vernon Chambers, W.C.*

Jan. 28, 1913. Sheppard, Edwd. Jas., F.R.M.S.
137, *Kennington Road, S.E.*

Mar. 25, 1913. Shuckard, David Hy.
14, *Walerand Road, Lewisham, S.E.*

Feb. 28, 1911. Sidebottom, Henry
"*Woodstock,*" *Syddal Park, Bramhall, Cheshire.*

June 19, 1896. Sidwell, Clarence J. H., F.R.M.S. (*Hon. Curator*)
46, *Ashbourne Grove, Dulwich, S.E.*

Feb. 22, 1910. Simpson, Norman Douglas
Carlton Mincott Vicarage, Thirsk, Yorks.

Oct. 26, 1903. Skorikow, Alexander Stepanovic
Musée Zoologique de l'Académie Impériale des Sciences, St. Petersburg, Russia.

Date of Election.	
Oct. 21, 1904.	Smith, Arthur Edgar *"Helios,"* 71, *Fox Lane, Palmer's Green, N.*
Mar. 25, 1870.	Smith, F. L. 3, *Grecian Cottages, Crown Hill, Norwood, S.E.*
Mar. 17, 1899.	Smith, Frank P. 2, *King's Villas, Chase Road, Southgate.*
Mar. 17, 1905.	Smith, Frederick 13, *Rye Hill Park, Peckham Rye, S.E.*
Nov. 18, 1898.	Smith, Thomas J., F.R.M.S. *c/o W. Watson & Sons,* 313, *High Holborn, W.C.*
Jan. 15, 1892.	Soar, C. D., F.L.S., F.R.M.S. 37, *Dryburgh Road, Putney, S.W.*
April 21, 1899.	Spitta, Edmund J., L.R.C.P., M.R.C.S., F.R.A.S., F.R.M.S. (*Vice-President*) 41, *Ventnor Villas, Hove, Brighton.*
April 21, 1899.	Spitta, Harold R. D., M.D., M.R.C.S., L.R.C.P., D.P.H. 12, *Bolton Street, Mayfair, W.*
Jan. 15, 1904.	Sprague, T. B., LL.D. 29, *Buckingham Terrace, Edinburgh.*
Dec. 23, 1913.	Sprenger, Hy. Fdk. Wm. 64, *Hallam Street, Portland Place, W.*
Jan. 28, 1913.	Spry, Lt. Robt., R.N., F.R.M.S. 83, *Mount Gold Road, Plymouth.*
Jan. 18, 1907.	Stahl, Arthur 11, *Scotts Avenue, Shortlands, Kent.*
Nov. 16, 1906.	Stephens, Samuel Phillips 15, *Green Street, Kimberley, Cape Colony.*
Nov. 27, 1885.	Stevenson, G. T. *Ravenscourt, Haling Park Road, South Croydon.*
June 18, 1897.	Still, Arthur L. *Roslyn, Dower Avenue, Wallington.*
Nov. 16, 1894.	Stokes, William B. 212, *Notre Dame Street, West Montreal.*
Dec. 15, 1893.	Sturt, Gerald *"Lismore," Cavendish Road, Weybridge.*

Date of Election.

Dec. 17, 1875. Swift, M. J., F.R.M.S.
6, *Aylestone Avenue, Brondesbury, N.W.*

Nov. 28, 1879. Tasker, J. G.
30, *Junction Road, Upper Holloway, N.*

Oct. 16, 1896. Taverner, Henry, F.R.M.S.
319, *Seven Sisters Road, Finsbury Park, N.*

May 24, 1910. Taylor, Charles Ernest
178, *Uxbridge Road, West Ealing.*

Feb. 17, 1905. Taylor, Thomas George
Ballaclague, Ellington Park Road, Ramsgate.

Dec. 22, 1865. Terry, John
8, *Hopton Road, Coventry Park, Streatham, S.W.*

Feb. 28, 1911. Thomas, Edwin Harvey

Mar. 26, 1912. Tibble, Bertie Wallace
27, *St. Paul's Road, Canonbury, N.*

June 24, 1913. Tierney, Clarence M. S., F.R.M.S.
10, *Enmore Park, Norwood, S.E.*

May 16, 1902. Tilling, George, F.R.M.S.
"*Grasmere,*" *Rydal Road, Streatham, S.W.*

Nov. 25, 1913. Tilling, Wm. Geo.
20, *Streathbourne Road, Upper Tooting, S.W.*

Jan. 25, 1910. Todd, Charles Stephen
25, *Hanover Road, Tottenham, N.*

Feb. 27, 1912. Tomlinson, Edwd. Theodore
8, *St. George's Square, S.W.*

Nov. 26, 1912. Tonkin, Thos. S.
Bramley Avenue, Coulsdon, Surrey.

Dec. 21, 1894. Traviss, Will. R.
42, *Winchester Avenue, Brondesbury, N.W.*

Feb. 25, 1913. Trotman, Alex. Chas.
28, *Gubyon Avenue, Herne Hill, S.E.*

Mar. 5, 1909. Troughton, Henry George
3, *New Court, Lincoln's Inn, W.C.*

Date of Election.

May 15, 1903. Tupman, Lt.-Col. G. Lyon, F.R.M.S.
College Road, Harrow.

June 17, 1892. Turner, C.
20, *Minster Road, Cricklewood, N.W.*

Feb. 25, 1913. Tyas, Rev. Vetranio
12, *Felstead Road, Wanstead, N.E.*

June 21, 1901. Tyrell, E. G. Harcourt
Park Rynie, Natal, S.A.

Mar. 16, 1906. Vogeler, Gustav
17, *Philpot Lane, E.C.*

Jan. 24, 1914. Walker, Arthur
306, *South Lambeth Road, S.W.*

July 25, 1873. Walker, J. S.
6, *Warwick Road, Upper Clapton, N.E.*

Nov. 22, 1910. Watts, Geo. W.
103, *Haverstock Hill, N.W.*

Dec. 21, 1900. Webster, Rev. T.

June 16, 1899. Wedeles, James, F.R.M.S.
231, *Flinders Lane, Melbourne, Australia.*

May 28, 1912. Weiss, Robt.
7 & 8, *Idol Lane, E.C.*

Mar. 20, 1908. West, Joshua Cobbett
20, *Millbrook Road, Brixton, S.W.*

Feb. 25, 1876. Wheeler, George
64, *Canonbury Park South, N.*

Jan. 25, 1910. Whitehead, Henry, B.Sc. Lond.
Wadham House, Toynbee Hall, Commercial Road, E.

Nov. 26, 1912. Whitteron, Fred.
Geelong, Victoria.

Dec. 4, 1908. Wilkins, Thomas Smith
Eversley, Uttoxeter.

Nov. 23, 1877. Williams, G. S.
Tor Hill, Kingskerswell, Devon.

Jan. 19, 1906. Wilson, Joseph, F.R.M.S.
Hillside, Avon Road, Upper Waltham stow, Essex.

Date of Election.

Feb. 27, 1912. Wood, Fredk. Geo.
161, *Walworth Road, S.E.*

Dec. 20, 1895. Wood, Walter J., F.R.M.S.
"Ernecroft," Abbey Road, Grimsby.

Nov. 16, 1894. Wooderson, Edwin
"Königsfeld," 39, Dartmouth Road, Brondesbury, N.W.

Mar. 15, 1907. Worssam, Cecil
17, *Grafton Road, Bedford.*

Jan. 18, 1907. Wright, Joseph Pepper
c/o Messrs. Davidson, Boules, Ld., 86, Wellington Street, West Toronto, Canada.

Feb. 21, 1902. Wyatt, Edward
Gordonia, Gloucester Road, Norbiton, Kingston.

Jan. 18, 1901. Wykes, William
7, *Plaistow Park Road, Plaistow, Essex.*

Mar. 24, 1914. Yermoloff, His Excellency Nicholas, K.C.V.O.
3, *Whitehall Court, S.W.*

Nov. 23, 1888. Young, G. W., F.G.S.
20, *Grange Road, Barnes, S.W.*

Nov. 15, 1907. Zehetmayr, Walter E.
Belle Vue, St. Margaret's, Twickenham.

Dec. 19, 1902. Zimmerman, Prof. C., F.R.M.S.
Collegio, Antonio Viera, Bahia, Rua do Sodré 43, Brazil.

NOTICE.

Members are requested to give early information to the Treasurer of any change of residence, so as to prevent miscarriage of Journals and Circulars.

List of Exchanges and of Societies, etc., which Receive the Journal.

An die Redaktion des "Mikrokosmos," Pfizerstrasse, 5, Stuttgart, Germany.
American Microscopical Society, T. W. Galloway, Secretary, Decatur, Ill., U.S.A.

Bausch & Lomb Optical Company, Publication Department, Rochester, N.Y., U.S.A.
Bergens Museums Bibliothek, Bergen, Norway.
Birkbeck College, Bream's Buildings, Chancery Lane, W.C.
Birmingham Natural History and Philosophical Society, Norwich Union Chambers, Congreve Street, Birmingham.
Botanical Society of Edinburgh (The Curator), The Botanic Gardens, Edinburgh.
Botanisches Centralblatt, c/o Dr. J. P. Lotsy, Spaarne 17, Haarlem, Holland.
Brighton and Hove Natural History Society, c/o The Public Library, Brighton.
Bristol Naturalists' Society (The Librarian), 5, Lansdown Place, Clifton, Bristol.
British Association for the Advancement of Science, Burlington House, London, W.

Canadian Institute, W. H. Vandersmitten, Esq., Secretary, 46, Richmond Street East, Toronto, Canada.
Concilium Bibliographicum, Zürich-Neumünster, Switzerland.
Croydon Natural History and Scientific Society (The Secretary), Public Hall, Croydon.

Dohrn, Prof. Reinhart, The Zoological Station, Naples.

"English Mechanic," 5, Effingham House, Arundel Street, W.C.
Entomological Society, 11, Chandos Street, Cavendish Square, W.
Essex Field Club, Essex Museum of Natural History, Stratford, Essex.

Geologists' Association (The Librarian), University College, Gower Street, W.C.

Herts Natural History Society, c/o Daniel Hill, Esq., "Herga," Watford, Herts.
Historical and Scientific Society of Manitoba, Winnipeg, Canada.
Horniman Museum, Forest Hill, S.E. (The Curator).
Hull Scientific and Field Naturalists' Club, Royal Institution, Hull.

Illinois State Laboratory of Natural History (Library), Urbana, Ill., U.S.A.
Imperial Leopold-Caroline Academy, Halle-an-der-Saale, Germany.

"Knowledge," The Knowledge Publishing Co., Ltd., 42, Bloomsbury Square, W.C.

Leicester Literary and Philosophical Society, Dr. Stracey, Hon. Librarian, Priory Lodge, New Walk, Leicester.
Library, Bureau of Science, Manila, Philippines.
Linnean Society, Burlington House, Piccadilly, W.
Literary and Philosophical Society of Manchester (The Librarian), 36, George Street, Manchester.
Lloyd Library, Cincinnati, Ohio, U.S.A.
Manchester Microscopical Society, J. E. Storey, Esq., 26, Grosvenor Road, Whalley Range, Manchester.
Microscopical Society of Liverpool, Royal Institution, Colquitt Street, Liverpool.

Missouri Botanical Garden, St. Louis, Mo., U.S.A.

Natural History Society of Northumberland, Durham, and Newcastle-upon-Tyne (The Librarian), Hancock Museum, Barras Bridge, Newcastle-upon-Tyne.
Natural History Branch of the British Museum (The Librarian), South Kensington, W.
Natural History Society of Glasgow (The Librarian), 207, Bath Street, Glasgow.
"Nature" (The Editor), St. Martin's Street, W.C.
Netherlands Zoological Society, Zoological Station, Helder, Holland.
"Nuova Notarisia," c/o Prof. G. B. De Toni, Université Royale de Modena, Modena, Italy.
"Nyt Magazin for Naturaidenskaberne," c/o Prof. Dr. N. Wille, Botan. Garten, Christiania.

Oberhessische Gesellschaft für Natur- und Heilkunde, Giessen, Germany.
Optical Society (The Hon. Librarian), 39, Victoria Street, S.W.

Patent Office Library, 25, Southampton Buildings, Chancery Lane, W.C.
Philadelphia Academy of Natural Sciences, Philadelphia, Pa., U.S.A.
Philippine Exposition Board, Calle General Solano 384, Manila, Philippine Islands.

R. Scuola Superiore di Agricoltura, Portici, Italy.
Royal Dublin Society, Leinster House, Dublin.
Royal Institute of Cornwall, Truro.
Royal Institution, 21, Albemarle Street, W.
Royal Society of Medicine, 1, Wimpole Street, W.
Royal Microscopical Society, 20, Hanover Square, W.
Royal Society, Burlington House, Piccadilly, W.
Royal Society of New South Wales, Sydney.
Royal Society of Arts, John Street, Adelphi, W.C.

Saunders, Sibert, Esq., 197, Amesbury Avenue, Streatham Hill, S.W.

Smithsonian Institution, Washington, D.C.
Smithsonian Institution (United States National Museum), c/o Wm. Wesley & Son, 28, Essex Street, Strand.
Société Belge de Microscopie, c/o Mons. A. Castaigne, 28, Rue de Berlaimont, Bruxelles.
Société Botanique Italienne, Florence, Italy.

Tempère, Mons. J., Grèz-sur-Loing, par Bourron, Seine et Marne.

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